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Structural Determinants of Green Growth: The Role of Institutions in Developing Economies

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ABSTRACT

Despite growing policy emphasis on green growth (GG), many developing economies continue to experience weak renewable energy transitions, raising concerns about whether prevailing development trajectories are compatible with environmental sustainability. This study examines how key structural determinants, foreign direct investment (FI), financial development (FD), urbanization level (UL), population growth (PG), and human capital (HC), affect GG, with particular attention to the under-researched moderating and nonlinear role of institutional quality (IQ). Using a balanced panel of 96 developing countries covering 2004–2023, the analysis applies panel-corrected standard errors and feasible generalized least squares to address cross-sectional dependence, heteroskedasticity, and serial correlation. The findings indicate that FI, FD, UL, and HC significantly undermine GG, suggesting that structural transformation in developing economies remains biased toward carbon-intensive activities. However, PG exerts a positive effect on GG, reflecting rising demand-driven incentives for renewable energy consumption. IQ displays a dual role: its direct effect on GG is negative, capturing persistent governance weaknesses, while its moderating effect is positive for FD and UL, indicating that stronger institutions can redirect these forces toward sustainable outcomes. No significant moderating influence is detected for FI, PG, or HC. Moreover, the results reveal a nonlinear threshold effect, whereby improvements in IQ enhance GG only after surpassing a critical level. Overall, the study highlights that GG in developing economies depends not only on structural change but also on institutional depth and effectiveness. The findings imply the need for governance reforms, targeted green finance, sustainable urban planning, and education reform.

1. Introduction

Developing economies pursue sustainable economic development while also dealing with serious challenges to environmental sustainability due to socio-economic and demographic factors. Policymakers and international organizations have focused on green growth (GG), a sustainable economic growth without compromising the needs of future generations, and efficient utilization of scarce resources. GG emphasizes renewable energy consumption (REC), eco-friendly investments, and technological progress to reduce transaction cost and optimize social wellbeing. In this context, it is essential to find the key factors that influence GG for effective policy formation in developing economies. Furthermore, this study aligns with and contributes to the attainment of the United Nations Sustainable Development Goals (SDGs), with a specific focus on SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), and SDG 16 (Peace, Justice, and Strong Institutions).

The study examines the impact of key structural factors on GG in developing economies. These determinants include foreign direct investment (FI), financial development (FD), urbanization level (UL), population growth (PG), and human capital (HC). FI is a major source of diffusion of technology which further enables environmental-friendly production (Osano & Koine, 2016; Sajid et al.,2021). However, many developing countries direct their FI towards carbon-intensive sectors due to their established structure and higher returns, supporting "Pollution Haven" hypothesis (Kim & Seok, 2023; Javorcik & Wei, 2003). Similarly, FD channels financial resources towards polluting industries due to lack of environmental regulations and short-term returns (Babatunde & Afolabi, 2024; Bolton & Kacperczyk, 2021; Cao et al., 2022).

Moreover, UL, which supports economies of scale and increases operational efficiency, causes serious environmental degradation in developing economies due to lack of planning and effective environmental regulations. Similarly, PG increases demand for energy which can be met using both non-renewable and renewable energy sources. However, in a resource-constrained economy, it may eventually encourage GG to meet the energy needs when institutional policies are aligned with environmental sustainability. Also, HC is believed to increase GG, but in many developing economies it is not positively associated with GG due to mismatch between education systems and skills required to adopt GG.

Institutional quality (IQ) is a potentially critical factor that links the aforementioned structural determinant to GG. Strong IQ, effective public policies, political stability, rule of law, and accountability and anti-corruption system (Hasan et al., 2022), essentially direct structural determinant toward GG. Conversely, weak IQ may cause the direction of funds towards carbon-intensive and polluting industries and undermine GG. Consequently, besides its direct effect on GG, IQ may also significantly moderate the impact of structural determinants.

Although, several empirical studies have examined GG and its determinants, significant gaps exist in literature. First, existing literature mainly focuses on the direct impact of FI, FD or UL on sustainability, the moderating role of IQ is unexplored, specifically in the context of developing economies. Second, the impact of structural factors on GG is mixed and inconsistent, suggesting that association depends on context. Third, most of the studies employ cross-sectional or time-series analysis, indicating a lack of empirical evidence on heterogenous dynamics of GG across panel studies. Lastly, the study is among the first to examine nonlinear IQ effects, suggesting a threshold beyond which it significantly expands GG.

The study contributes to the literature by addressing aforementioned gaps. Specifically, a sample of 96 developing economies was selected to obtain robust estimates. Furthermore, robust regression techniques such as panel corrected standard error (PCSE) and feasible generalized least squares (FGLS) were applied to obtain regression estimates. Additionally, the study examines the effects of structural determinants (e.g., "FI, FD, UL, PG, & HC") on GG, considering the moderating effects of IQ and its nonlinear effects on GG. In sum, the study provides robust and multi-dimensional evidence on how socio-economic and demographic factors along with IQ impact GG in emerging economies.

2. Literature Review
2.1 Theoretical Background:

The relationship between structural determinants, IQ and GG can be explained through several theories and models. This study adopts two most relevant theories such as Environmental Kuznet Hypothesis (EKH) proposed by Grossman and Krueger (1991) and the Institutional theory (ITT) initially proposed by North (1990). The EKH postulates that a country experiences higher environmental degradation initially as its income rises due to rapid industrialization, but it starts to decrease as the country surpasses a certain level of income, making an inverted U-shaped relationship. This model indicates the trade-off between development and GG in the early stages of development. Specifically, EKH implies that developing economies direct capital flows towards carbon-intensive industries, reducing GG until public policy and institutional reforms retransmit them towards sustainable use (Liang & Yang, 2019). Moreover, ITT argues that strong institutions and governance are necessary conditions for sustainable development. The theory emphasizes that institutions affect economic performance of a country by creating incentives, reducing transaction cost and risk, and providing and securing property rights. In the context of REC, higher IQ encourages GG by ensuring effective regulations, reducing corruption, and directing funds into sustainable renewable energy and environmentally friendly technologies. On the contrary, economies with weak institutions and poor IQ may depend on carbon-intensive projects, slowing GG. These theories, together, provide a theoretical foundation to this study for examining how socio-economic and demographic factors (FI, FD, UL, PG, HC) interact with IQ to affect GG in developing economies.

2.2 Review of Empirical Literature: Development of Hypotheses
2.2.1 Financial Development and Green Growth

FD plays a significant role in expanding access to credit and channel funds towards productive use in an economy. The funds can be used to increase renewable energy use or to generate energy from conventional ways, dependence on fossil fuel. Empirical literature provides mixed findings on the relationship between FD and GG. Several studies found that higher FD encourages GG by providing decreasing financing constraints for renewable energy project (Ahmad et al., 2024; Solaymani & Montes, 2024). However, other studies found that funds are often diverted towards well-established and carbon-intensive sectors to higher returns and lower risk in developing economies (Bolton & Kacperczyk, 2021; Cao et al., 2022; Prasad et al., 2022). So, FD may encourage or undermine GG depending on the financing mechanism and preference of policymakers. So, the study proposes the following hypothesis:

H_1: Financial Development significantly affects Green Growth in developing economies.

2.2.2 Foreign Direct Investment and Green Growth

FI supports technology transfer which facilitates GG in an economy (Osano & Koine, 2016; Sajid et al.,2021). However, many developing economies still receive significant share of their FI in carbon-intensive and polluting industries, increasing dependence on fossil-fuel consumption (Sarkodie & Strezov, 2019). This is known as "Pollution Haven" hypothesis, suggesting that foreign investors exploit weak environmental regulations (Javorcik & Wei, 2003). Studies provide mixed effects of FI on GG, depending on the nature of capital inflows and its sectoral distribution (Arzova & Şahin, 2024). So, the study proposes the following hypothesis:

H_2: Foreign Direct Investment significantly affects Green Growth in developing economies.

2.2.3 Urbanization and Green Growth

UL promotes GG by creating economies of scale in infrastructure and allocation of energy (Quaas & Smulders, 2018). On the other hand, unplanned urban sprawl with weak environmental regulations may increase the dependence on non-renewable resources and fossil fuel consumption due to higher energy demand (Wang et al., 2022). Several studies found that UL in developing economies may create severe scarcity of productive resources and contribute to higher pollution, slowing GG (Chen et al., 2022; Liang & Yang, 2019; Shamaee et al., 2024). Thus, the following hypothesis is proposed:

H_3: Urbanization has a significant impact on Green Growth in developing economies.

2.2.4 Population Growth and Green Growth

Generally, PG expands the demand for energy which can encourage GG or intensify the reliance on non-renewable energy sources (Samways, 2022; Tawiah et al., 2021). Economies where the major portion of energy is derived from fossil fuels, higher PG may increase environmental degradation

(Kartal, 2022). On the contrary, higher PG may put pressure on adopting renewable energy options to fulfil energy needs in a resource-constrained economy (Jabbour Al Maalouf et al., 2024; Marzouk & Mahrous, 2020). Empirical literature provided mixed results, indicating context dependency. So, the following hypothesis is proposed:

H[4]: Population Growth significantly affects Green Growth in developing economies.

2.2.5 Human Capital and Green Growth

HC provides knowledge, improves skills and enables people to adopt renewable energy technologies (Li et al., 2022; Liu et al., 2023; Ngo et al.,2022). In practice, in many developing economies, the education systems are not aligned with such skills and higher HC does not encourage GG (Mishra, 2017; Pavlova, 2018). In fact, several studies found a significant negative association between HC and GG (Shao et al., 2025), indicating a mismatch between educational system and environmental concerns (Jagannathan, 2013). So, the following hypothesis is proposed:

H[5]: Human Capital significantly affects Green Growth in developing economies.

2.2.6 Institutional Quality and Green Growth

IQ has a significant moderating role in the relationship between structural determinants and GG in developing economies (Ahmed et al., 2022; Khan et al., 2022). For example, strong institutions not only direct FI towards renewable energy projects, but also encourage green finance, implement sustainable urban planning, and link HC with GG (Sajid et al., 2023; Sun et al., 2025). On the contrary, weak institutions may discourage and undermine GG and expand the dependence on non-renewable sources of energy (Babatunde & Afolabi, 2024). Although several studies demonstrate that IQ moderates the association between structural determinants and GG (Ahmed et al., 2022; Babatunde & Afolabi, 2024; Jahanger et al., 2022; Khan et al., 2022; Sajid et al., 2023; Sun et al., 2025), its effectiveness is unclear in the context of developing economies. Therefore, the following hypothesis is proposed:

H[6]: Institutional Quality significantly moderates the relationship between structural determinants and Green Growth in developing economies.

3. Methodology

3.1 Data, Sample and Variables

A sample of ninety-six developing economies was selected for the period of 2004-2023 making 1920 panel observations. The study classified countries as developing based on the income criteria by the World Bank. Furthermore, the choice of the sample is based on the significance of GG for developing economies and data availability. The data for the study were collected from two main sources i.e., the World Bank and the United Nations Conference on Trade and Development (UNCTAD). The measurement and description of the variables are discussed in Table 1.

Table 1. Description and Measurement of Variables

Category	Variable	Description	Measurement
Dependent Variable	GG	Green growth proxied by renewable energy consumption	Energy Consumption as a % of total final energy consumption.
Economic Factor	FI	Foreign Direct Investment.	Net Inflows of FI (% of GDP).
	FD	Financial Development	Domestic credit to private sector (% of GDP).
Institutional Factor	IQ	Institutional Quality (Composite Index)	Constructed via PCA from six governance indicators: political stability, government effectiveness, rule of law, regulatory quality, control of corruption, and voice & accountability (World Bank WGI). Standardized (mean = 0, SD = 1).
Socio-Demographic Factors	UL	Urbanization Level	Urban population (% of total population).
	PG	Population Growth	Annual % change in total population.
	HC	Human Capital	Gross secondary school enrollment (%).

3.2 Composite Index of IQ using PCA

IQ is constructed using six governance indicators (mentioned in Table 1). The data of these indicators were obtained from the World Bank. The study combined these indicators into a composite index using Principal Component Analysis (PCA). The PCA extracted and standardized (Mean = 0, SD =1) the first principal component, capturing the highest common variance across indicators.

3.3 Statistical Analysis and Econometric Model

In this section, specific econometric model and statistical analyses are discussed. First, the study performed descriptive and correlational analyses to better understand the data. Second, panel corrected standard errors (PCSE) regression method is used (Beck & Katz, 1995) to test the hypotheses developed in the previous section. Moreover, to revalidate the findings of PCSE, the regression models were re-estimated through Feasible Generalized Least Squares (FGLS) regression approach. The baseline model of the study is specified as:

$$G_{it}=\beta_0+\beta_1 FI_{it}+\beta_2 FD_{it}+\beta_3 UL_{it}+\beta_4 PG_{it}+\beta_5 HC_{it}+\gamma_i+\lambda_t+\mu_{it} \tag{1}$$

The extended specification incorporates IQ, its moderating role and nonlinear effects:

$$GG_{it}=\beta_0+\beta_1 FI_{it}+\beta_2 FD_{it}+\beta_3 UL_{it}+\beta_4 PG_{it}+\beta_5 HC_{it}+\beta_6 IQ_{it}+\beta_7 (FI\times IQ)+\gamma_i+\lambda_t+\mu_{it} \tag{2}$$
$$GG_{it}=\beta_0+\beta_1 FI_{it}+\beta_2 FD_{it}+\beta_3 UL_{it}+\beta_4 PG_{it}+\beta_5 HC_{it}+\beta_6 IQ_{it}+\beta_7 (FD\times IQ)+\gamma_i+\lambda_t+\mu_{it} \tag{3}$$
$$GG_{it}=\beta_0+\beta_1 FI_{it}+\beta_2 FD_{it}+\beta_3 UL_{it}+\beta_4 PG_{it}+\beta_5 HC_{it}+\beta_6 IQ_{it}+\beta_7 (UL\times IQ)+\gamma_i+\lambda_t+\mu_{it} \tag{4}$$
$$GG_{it}=\beta_0+\beta_1 FI_{it}+\beta_2 FD_{it}+\beta_3 UL_{it}+\beta_4 PG_{it}+\beta_5 HC_{it}+\beta_6 IQ_{it}+\beta_7 (PG\times IQ)+\gamma_i+\lambda_t+\mu_{it} \tag{5}$$
$$GG_{it}=\beta_0+\beta_1 FI_{it}+\beta_2 FD_{it}+\beta_3 UL_{it}+\beta_4 PG_{it}+\beta_5 HC_{it}+\beta_6 IQ_{it}+\beta_7 (HC\times IQ)+\gamma_i+\lambda_t+\mu_{it} \tag{6}$$
$$GG_{it}=\beta_0+\beta_1 FI_{it}+\beta_2 FD_{it}+\beta_3 UL_{it}+\beta_4 PG_{it}+\beta_5 HC_{it}+\beta_6 IQ_{it}+\beta_7 IQ^2+\gamma_i+\lambda_t+\mu_{it} \tag{7}$$

where the models (2 to 6) are used to check the presence of moderation effects of IQ on the relationship between structural determinants and GG (captured by β_7). Furthermore, in model (7), the nonlinear effects of IQ is measured to confirm threshold effects. Additionally, country dummy (γ_i) and year dummy (λ_t) are included to account for unobserved heterogeneity in all models.

3.3   Diagnostic Analysis

The study performed few diagnostic tests before estimating the regression models. In particular, the variance inflation factor (VIF) is used to check the presence of multicollinearity. Furthermore, the Levin-Lin-Chu (LLC) panel unit root test is employed to check whether or not variables are stationary at level. Moreover, the Pesaran's (2021) cross-sectional dependence (CSD) test is used to check CSD among sample countries. The study also employs the Wooldridge test to detect serial correlation and the modified Wald test to assess heteroscedasticity within the data.

4. Results and Discussion

4.1   Descriptive Statistics and Normality Analysis

Descriptive statistics and normality analysis of the variables used in this study are reported in Table 2. The results show that the average GG is 34% with a great variation across sample economies (ranges from 0 to 92%). It reveals heterogeneous REC pattern among developing economies. Similarly, mean FI is found to be 3.93% with substantial variation (SD = 5%) and having negative and positive inflows indicating diverse FI dynamics. Also, FD has mean value of 41% (with SD of 30.48%) representing varied level of financial intermediation across the sample countries. Furthermore, UL's mean value is 51.51%, indicating that around half of population in developing economies live in urban region. The average PG is 1.39% with a minimum value of -8.42% reflecting downward trend in population in some countries.

Similarly, HC exhibits an average value of 75.19%, (with an SD of 19.85%), indicating moderate level of variation of school enrollment among countries. Moreover, IQ (constructed using PCA), is standardized with an average of zero and unit variance, shows minimum -2.61 (poor IQ) to 2.75 (strong IQ). Moreover, the Shapiro-Wilk statistics for all variables show that the panel data series do not follow normal distribution, justifying the application of PCSE and FGLS regression methods to estimate the relationships (Hasan et al., 2023).

Table 2. Descriptive Statistics and Normality Analysis

Variables	Mean	SD	Min.	Max.	Shapiro-Wilk Stat.
GG	33.676	26.304	0.000	92.000	0.926[a]
FI	3.934	5.007	-37.173	54.365	0.775[a]
FD	41.020	30.478	-1.469	194.674	0.880[a]
UL	51.512	19.236	12.978	92.463	0.981[a]
PG	1.388	1.238	-8.423	9.992	0.948[a]
HC	75.542	19.857	18.129	141.203	0.990[a]
IQ	0.000	1.000	-2.614	2.750	0.992[a]

Note: [a] shows significance at 1 percent level of significance.

4.2   Correlation Analysis and Multicollinearity

The results of Pearson's coefficient of correlation and VIF are reported in Table 3. The findings show interesting patterns: for example, GG has a significant negative correlation with FI, FD, UL, HC, and IQ, implying that higher level of FD, UL, HC, and IQ do not promote REC in developing economies. On the

other hand, higher PG has a significant positive correlation with GG, suggesting that higher population may increase demand for REC in developing economies.

Furthermore, FI has a weak positive association with FD and IQ, but FD has a strong positive correlation with HC and IQ, showing complementarities between them. Similarly, UL and HC have a positive correlation, consistent with the role of UL in encouraging access to education. The above correlations are significant at the 1% and 5% level of significance and none of them are high enough to create multicollinearity issue. Moreover, this is further examined by the VIF values, none is above the threshold of 10. So, multicollinearity does not exist, and all the explanatory variables can be included in the regression model reliably.

Table 3. Correlation Analysis & Multicollinearity

Variable	GG	FI	FD	UL	PG	HC	IQ	VIF
GG	1							n/a
FI	-0.136[a]	1						1.044
FD	-0.374[a]	0.131[a]	1					1.336
UL	-0.424[a]	0.050[b]	0.107[a]	1				1.101
PG	0.288[a]	-0.023	-0.294[a]	-0.055[b]	1			1.276
HC	-0.443[a]	0.080[a]	0.339[a]	0.285	-0.411	1		1.471
IQ	-0.261[a]	0.164[a]	0.452[a]	0.052b	-0.313	0.384	1	1.421

Note: [a, b] shows significance at 1% and 5% level of significance, respectively.

4.3 Panel Unit Root Test

The findings of the LLC panel unit root test are reported in Table 4. The results indicate that all variables are stationary at level, rejecting the null hypothesis of a unit root for all variables, suggesting no need for differencing for including in the econometric models.

Table 4. Results of LLC Panel Unit Root Test

Variable	Adj. t-statistic	Decision	Conclusion
GG	-5.898[a]	Rejecting H_0	Stationary at Level
FI	-6.624[a]	Rejecting H_0	Stationary at Level
FD	-5.270[a]	Rejecting H_0	Stationary at Level
UL	-9.079[a]	Rejecting H_0	Stationary at Level
PG	-10.786[a]	Rejecting H_0	Stationary at Level
HC	-1.953[b]	Rejecting H_0	Stationary at Level
IQ	-5.295[a]	Rejecting H_0	Stationary at Level
IQ^2	-5.544[a]	Rejecting H_0	Stationary at Level

Note: [a, b] indicates significance at 1% and 5% level of significance, respectively. H_0: Panels contain unit roots

4.4 Diagnostic Analysis

The results of key diagnostic tests, including Pesaran's CSD test, the Modified Wald test for heteroscedasticity, and the Wooldridge test for serial correlation, are reported in Table 5. The results reject the null hypothesis CSD test of 'No Cross Section Dependence" at the 1% significance level,

confirming interdependence across the sampled countries. This suggests that economic shocks or policy changes in one economy spill over to others, showing strong cross-country linkages. Likewise, the modified Wald test confirms the presence of heteroscedasticity, and the Wooldridge test indicates the first-order serial correlation. These diagnostics are consistent across all model specifications. Based on these findings, the study employs the Panel-Corrected Standard Errors (PCSE) estimator to obtain efficient and reliable inference (Beck & Katz, 1995; Hasan et al., 2024).

Table 5. Diagnostic Tests

Test	Test Statistic
Pesaran's CSD tests statistics	3.304[a]
Wooldridge test for serial correlation	244.479[a]
Modified Wald test for heteroscedasticity	56307.48[a]

Note: [a] shows significance at 1 percent level of significance

4.5   Regression Results

The empirical findings of the regression models (1) to (7) using PCSE are presented in Table 6. The results reveal that FI has a negative and statistically significant effect on GG, implying that developing economies tend to receive FI in carbon-intensive and non-renewable sectors instead of renewable energy industries which undermine GG. Similarly, the coefficient of FD shows an adverse impact on GG, implying that higher access to credit and growth of financial sector prefer investments in established carbon-intensive and established fossil-fuel industries rather than renewable energy projects. Financial institutions choose these sectors because of higher short-term returns, lower risks, and deep-rooted market structures. Therefore, targeted green finance mechanisms are required to channel funds towards renewable industries.

Furthermore, UL has a negative relationship with GG. Although urbanization encourages economies of scale and efficient distribution of energy, higher energy demand is fulfilled through non-renewable energy sources i.e., fossil-fuel, natural gas, and coal. In other words, higher UL increases dependence on non-renewable energy sources due to weak environmental regulations, urban planning, and the lack of green infrastructure. Moreover, the findings show a significant and negative relationship between HC and GG. The results suggest that educational progress, specifically in developing economies, has not diverted preference towards REC. The possible reason for this relationship is a mismatch between educational attainment and the managerial ability to adopt renewable energy because schooling systems, in many developing economies, do not focus on necessary training that help adopt GG. Consequently, higher HC does not necessarily contribute to renewable energy transitions, suggesting the need for education reforms towards green skills and sustainability-focused curricula. On the other hand, PG shows a significant positive association with GG. The results imply that increasing population may increase demand for energy consumption which cannot be met using conventional energy sources and promote REC in developing economies.

Moreover, the results show that IQ is a significant determinant of GG in developing economies. The results show that the direct impact of IQ on GG is negative, suggesting that weak institutions hamper GG in developing economies. Conversely, IQ positively moderates the impact of FD and UL on GG, implying that good governance and strong institutions may transmit FD and UL into green transition. However, the moderating effects of IQ on the FI-GG, PG-GG, and HC-GG links are statistically insignificant. The findings imply that institutions are not strong enough to redirect FI, PG and HC into REC. Also, the coefficient of IQ^2 is significant and positive, highlighting the presence of a nonlinear relationship between IQ and GG in developing economies. This implies that IQ may substantially increase GG to a higher level beyond a threshold.

Table 6. Regression results of GG: PCSE

Variables	1	2	3	4	5	6	7	Sign
FI	-0.041[b]	-0.042[b]	-0.038[c]	-0.040[b]	-0.041[b]	-0.040[b]	-0.041[b]	Negative
	(0.020)	(0.019)	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)	
FD	-0.124[a]	-0.105[a]	-0.109[a]	-0.100[a]	-0.103[a]	-0.102[a]	-0.103[a]	Negative
	(0.022)	(0.019)	(0.019)	(0.019)	(0.019)	(0.018)	(0.019)	
UL	-0.539[a]	-0.533[a]	-0.530[a]	-0.533[a]	-0.533[a]	-0.533[a]	-0.533[a]	Negative
	(0.045)	(0.040)	(0.041)	(0.040)	(0.041)	(0.040)	(0.041)	
PG	0.432[b]	0.416[b]	0.382[b]	0.363[b]	0.431[b]	0.385[b]	0.394[b]	Positive
	(0.169)	(0.171)	(0.164)	(0.158)	(0.171)	(0.164)	(0.166)	
HC	-0.026[a]	-0.024[a]	-0.023[a]	-0.023[a]	-0.023[a]	-0.023[a]	-0.023[a]	Negative
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	
IQ		-3.739[a]	-4.900[a]	-10.896[a]	-3.886[a]	-3.727[a]	-3.748[a]	Negative
		(0.488)	(0.699)	(1.568)	(0.565)	(0.923)	(0.467)	
FI×IQ		-0.005						Insignificant
		(0.026)						
FD×IQ			0.030[b]					Positive
			(0.012)					
UL×IQ				0.143[a]				Positive
				(0.026)				
PG×IQ					0.140			Insignificant
					(0.191)			
HC×IQ						0.000		Insignificant
						(0.010)		
IQ^2							0.269[a]	Positive
							(0.123)	
Intercept	68.377[a]	67.213[a]	66.790[a]	66.823[a]	67.112[a]	67.036[a]	66.790[a]	
	(2.689)	(2.450)	(2.480)	(2.407)	(2.474)	(2.493)	(2.498)	
Wald Chi^2	174.59[a]	256.51[a]	258.69[a]	286.53[a]	246.91[a]	243.18[a]	248.12[a]	
R^2	0.457	0.477	0.477	0.487	0.476	0.475	0.476	
Rho	0.920	0.916	0.920	0.920	0.919	0.920	0.919	

Note: [a,b] indicates significance at 1% and 5% percent level of significance, respectively.

Furthermore, the study performs a robust analysis by estimating the regression models (1) to (7) using FGLS. The results of FGLS are reported in Table 7. Although slight variations in coefficients magnitude are detected, the findings of FGLS confirm and validate PCSE results, showing consistency across both methods that FI, FD, UL decreases GG, while PG enhances it. Additionally, IQ has a mixed

but significant impact on GG. In general, the findings demonstrate that both developmental and structural factors tend to weaken GG in developing economies. On the other hand, institutions and governance have the potential to lessen these negative effects and transmit growth trajectories toward sustainable green energy use.

Table 7. Robustness Regression results of GG : FGLS

Variables	1	2	3	4	5	6	7	Sign
FI	-0.048[a]	-0.048[a]	-0.043[a]	-0.045[a]	-0.047[a]	-0.046[a]	-0.046[a]	Negative
	(0.017)	(0.018)	(0.016)	(0.017)	(0.017)	(0.016)	(0.016)	
FD	-0.086[a]	-0.085[a]	-0.090[a]	-0.075[a]	-0.082[a]	-0.081[a]	-0.083[a]	Negative
	(0.010)	(0.009)	(0.010)	(0.009)	(0.009)	(0.009)	(0.009)	
UL	-0.602[a]	-0.592[a]	-0.587[a]	-0.608[a]	-0.594[a]	-0.593[a]	-0.590[a]	Negative
	(0.021)	(0.020)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	
PG	0.419[b]	0.420[b]	0.397[b]	0.383[b]	0.414[b]	0.399[b]	0.382[b]	Positive
	(0.171)	(0.164)	(0.176)	(0.189)	(0.194)	(0.191)	(0.182)	
HC	-0.016[a]	-0.017[a]	-0.017[a]	-0.015[a]	-0.016[a]	-0.016[a]	-0.016[a]	Negative
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	
IQ		-2.628[a]	-3.595[a]	-9.455[a]	-2.645[a]	-3.010[a]	-2.746[a]	Negative
		(0.338)	(0.495)	(0.882)	(0.362)	(0.588)	(0.344)	
FI×IQ		0.001						Insignificant
		(0.018)						
FD×IQ			0.021[b]					Positive
			(0.008)					
UL×IQ				0.127[a]				Positive
				(0.015)				
PG×IQ					0.073			Insignificant
					(0.127)			
HC×IQ						0.006		Insignificant
						(0.006)		
IQ^2							0.382[b]	Positive
							(0.194)	
Intercept	66.305[a]	66.201[a]	65.831[a]	66.264[a]	66.122[a]	65.964[a]	65.598[a]	
	(1.324)	(1.288)	(1.314)	(1.360)	(1.307)	(1.315)	(1.322)	
Wald Chi²	1060.72[a]	1224.72[a]	1173.05[a]	1162.08[a]	1175.66[a]	1162.24[a]	1188.07[a]	
Pseudo-R²	0.251	0.286	0.288	0.315	0.285	0.284	0.284	
rho	0.925	0.920	0.925	0.925	0.924	0.925	0.924	

Note: [a, b] indicates significance at 1% and 5% percent level of significance, respectively.

5. Conclusion

The study examined the key structural determinants of GG in developing economies, with a particular focus on the moderating role of IQ. A sample of 96 developing countries from 2004-2023 were used and robust panel regression techniques were used to estimate relationships. The findings reveal that FD, FI, UL, and HC tend to weaken GG, while population growth (PG) encourages renewable energy use in the sample economies. Interestingly, the empirical findings reveal a negative and significant direct effect of IQ on GG, but the findings show that it has the potential to redirect FD and UL towards positive effect on GG. Conversely, IQ fails to moderate the effects of FI, PG, and HC highlighting the persistent weaknesses and issues of institutions in many developing countries.

This study significantly contributes to the body of knowledge by providing insights that GG is not only dependent on socio-economic and demographic factors but also determined greatly by the institutional and governmental framework. Also, the results show the presence of nonlinear effects of IQ which implies that significant institutional and policy reforms are required to surpass the threshold beyond which IQ may redirect socio-economic and demographic dynamic towards REC.

Furthermore, the study provides useful policy implications. First, government and policy makers must improve environmental regulations to channel FI towards GG and discourage carbon-intensive projects. Second, priority should be given to green-focused financing sectors by financial sector to increase financial returns and reduce risk. Third, proper urban planning aligned with sustainability targets, and educational reforms which incorporate green skills to ensure that HC increases GG should be in the list of policy reforms. Lastly, IQ must be improved as it shapes and moderates the effects of structural factors on GG.

Furthermore, the study has several limitations. First, the analysis is mainly based on country-level data, which may not capture within-country complexity in the GG process and could thus limit the generalizability of the findings for each country at localized levels. Secondly, data limitations constrained the inclusion of some key determinants and nuanced measures of IQ and GG. This may limit our ability to fully capture the role of informal institutions and country-specific policy differences

In future research it would be convenient to take into account microlevel or sector-specific data to reflect regional and industrial heterogeneity. It can also explore alternative measures of GG and IQ, as well as nonlinear and threshold effects between income category groups. The application of dynamic panel methods or causal identification strategies could contribute to improve our knowledge on long-term interaction between structural factors, IQ, and GG.

References

Ahmad, M., Ahmed, Z., Alvarado, R., Hussain, N., & Khan, S. A. (2024). Financial development, resource richness, eco-innovation, and sustainable development: Does geopolitical risk matter?. *Journal of Environmental Management*, *351*, 119824. https://doi.org/10.1016/j.jenvman.2023.119824

Ahmed, F., Kousar, S., Pervaiz, A., & Shabbir, A. (2022). Do institutional quality and financial development affect sustainable economic growth? Evidence from South Asian countries. *Borsa Istanbul Review*, *22*(1), 189-196. https://doi.org/10.1016/j.bir.2021.03.005

Arzova, S. B., & Şahin, B. Ş. (2024). Macroeconomic and financial determinants of green growth: an empirical investigation on BRICS-T countries. *Management of Environmental Quality: An International Journal*, *35*(3), 506-524. https://doi.org/10.1108/MEQ-07-2023-0210

Babatunde, M. A., & Afolabi, J. A. (2024). Advancing sustainable industrial development in Africa: the role of institutional quality and renewable energy. *Environment, Development and Sustainability*, 1-27. https://doi.org/10.1007/s10668-024-05170-8

Beck, N., & Katz, J. N. (1995). What to do (and not to do) with time-series cross-section data. *American political science review*, *89*(3), 634-647. https://doi.org/10.2307/2082979

Bolton, P., & Kacperczyk, M. (2021). Do investors care about carbon risk?. *Journal of financial economics*, *142*(2), 517-549. https://doi.org/10.1016/j.jfineco.2021.05.008

Cao, J., Law, S. H., Samad, A. R. B. A., Mohamad, W. N. B. W., Wang, J., & Yang, X. (2022). Effect of financial development and technological innovation on green growth—analysis based on spatial Durbin model. *Journal of Cleaner Production*, *365*, 132865. https://doi.org/10.1016/j.jclepro.2022.132865

Chen, M., Chen, L., Cheng, J., & Yu, J. (2022). Identifying interlinkages between urbanization and Sustainable Development Goals. *Geography and Sustainability*, *3*(4), 339-346. https://doi.org/10.1016/j.geosus.2022.10.001

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. https://doi.org/10.3386/w3914

Hasan, M. A., Abdullah, M., Hashmi, M. A., & Sajid, A. (2022). International Remittances and International Tourism Development in South Asia: The Moderating Role of Political Stability. *Journal of Economic Impact, 4*(3), 177-187. https://doi.org/10.52223/jei4032204

Hasan, M. A., Badar, S. N., Ghouri, A. A., & Saad, M. (2023). Trade, Foreign Capital, and Productive Capacity Nexus: The Moderating Role of Institutions. *iRASD Journal of Economics*, *5*(4), 1113-1129. https://doi.org/10.52131/joe.2023.0504.0183

Hasan, M. A., Siddiqui, A. A., Arsalan, M., & Sajid, A. (2024). The Moderating Role of Institutional Quality in the Relationship between Foreign Capital Inflows and Stock Market Development: A Panel Data Analysis. *Journal of Economic Impact*, *6*(2), 147-154. https://doi.org/10.52223/econimpact.2024.6205

Jabbour Al Maalouf, N., Sayegh, E., Inati, D., & Sarkis, N. (2024). Consumer motivations for solar energy adoption in economically challenged regions. *Sustainability*, *16*(20), 8777. https://doi.org/10.3390/su16208777

Jagannathan, S. (2013). Education and skills in Asia: Responding to greening economies. *Skills development for inclusive and sustainable growth in developing Asia-Pacific*, 265. https://doi.org/10.1007/978-94-007-5937-4_15

Jahanger, A., Usman, M., & Balsalobre-Lorente, D. (2022). Linking institutional quality to environmental sustainability. *Sustainable Development*, *30*(6), 1749-1765. https://doi.org/10.1002/sd.2345

Javorcik, B. S., & Wei, S. J. (2003). Pollution havens and foreign direct investment: Dirty secret or popular myth?. Contributions in Economic Analysis & Policy, 3(2). https://doi.org/10.2202/1538-0645.1244

Kartal, M. T. (2022). The role of consumption of energy, fossil sources, nuclear energy, and renewable energy on environmental degradation in top-five carbon producing countries. *Renewable Energy*, *184*, 871-880. https://doi.org/10.1016/j.renene.2021.12.022

Khan, M., Rana, A. T., & Ghardallou, W. (2022). Economic instability and pollution emissions in developing countries: A panel data investigation. *Energy & Environment*, *33*(7), 1465-1484. https://doi.org/10.1177/0958305X221091539

Kim, S. E., & Seok, J. H. (2023). The impact of foreign direct investment on CO2 emissions considering economic development: Evidence from South Korea. *The Journal of International Trade & Economic Development*, *32*(4), 537-552. https://doi.org/10.1080/09638199.2022.2122538

Li, X., Shaikh, P. A., & Ullah, S. (2022). Exploring the potential role of higher education and ICT in China on green growth. *Environmental Science and Pollution Research*, *29*(43), 64560-64567. https://doi.org/10.1007/s11356-022-20292-0

Liang, W., & Yang, M. (2019). Urbanization, economic growth and environmental pollution: Evidence from China. *Sustainable Computing: Informatics and Systems*, *21*, 1-9. https://doi.org/10.1016/j.suscom.2018.11.007

Liu, D., Wang, G., Sun, C., Majeed, M. T., & Andlib, Z. (2023). An analysis of the effects of human capital on green growth: effects and transmission channels. *Environmental Science and Pollution Research*, *30*(4), 10149-10156. https://doi.org/10.1007/s11356-022-22587-8

Marzouk, O. A., & Mahrous, A. A. (2020). Sustainable consumption behavior of energy and water-efficient products in a resource-constrained environment. *Journal of Global Marketing*, *33*(5), 335-353. https://doi.org/10.1080/08911762.2019.1709005

Mishra, P. (2017). Green human resource management: A framework for sustainable organizational development in an emerging economy. *International Journal of Organizational Analysis*, *25*(5), 762-788. https://doi.org/10.1108/IJOA-11-2016-1079

Ngo, T., Trinh, H. H., Haouas, I., & Ullah, S. (2022). Examining the bidirectional nexus between financial development and green growth: International evidence through the roles of human capital and education expenditure. *Resources Policy*, *79*, 102964. https://doi.org/10.1016/j.resourpol.2022.102964

Osano, H. M., & Koine, P. W. (2016). Role of foreign direct investment on technology transfer and economic growth in Kenya: a case of the energy sector. *Journal of Innovation and Entrepreneurship*, *5*(1), 31. https://doi.org/10.1186/s13731-016-0059-3

Pavlova, M. (2018). Fostering inclusive, sustainable economic growth and "green" skills development in learning cities through partnerships. *International Review of Education*, *64*(3), 339-354. https://doi.org/10.1007/s11159-018-9718-x

Pesaran, M. H. (2021). General diagnostic tests for cross-sectional dependence in panels. *Empirical economics*, *60*(1), 13-50. https://doi.org/10.1007/s00181-020-01875-7

Prasad, M. A., Loukoianova, M. E., Feng, A. X., & Oman, W. (2022). *Mobilizing private climate financing in emerging market and developing economies*. International Monetary Fund. https://doi.org/10.5089/9798400216428.066

Quaas, M. F., & Smulders, S. (2018). Brown growth, green growth, and the efficiency of urbanization. *Environmental and resource economics*, *71*(2), 529-549. https://doi.org/10.1007/s10640-017-0172-1

Sajid, A., Hashmi, M. A., Abdullah, A., & Hasan, M. A. (2021). Foreign capital inflows and stock market development in Pakistan. *The Journal of Asian Finance, Economics and Business, 8*(6), 543-552. https://doi.org/10.13106/jafeb.2021.vol8.no6.0543

Sajid, M., Ansari, M. A. A., Tanveer, A., Faheem, M., & Waseem, A. (2023). Evaluating the influence of green growth, institutional quality and financial inclusion on financial stability: evidence by

sustainable finance theory. *Environmental Science and Pollution Research*, *30*(54), 115965-115983. https://doi.org/10.1007/s11356-023-30362-6

Samways, D. (2022). Population and sustainability: Reviewing the relationship between population growth and environmental change. *The Journal of Population and Sustainability*, *6*(1), 15-41. https://doi.org/10.3197/JPS.63772239426891

Sarkodie, S. A., & Strezov, V. (2019). Effect of foreign direct investments, economic development and energy consumption on greenhouse gas emissions in developing countries. *Science of the total environment*, *646*, 862-871. https://doi.org/10.1016/j.scitotenv.2018.07.365

Shamaee, S. H., Yousefi, H., & Zahedi, R. (2024). Assessing urban development indicators for environmental sustainability. *Discover Sustainability*, *5*(1), 341. https://doi.org/10.1007/s43621-024-00563-1

Shao, Y., Syed, Q. R., & Zafar, R. F. (2025). The dynamic relationship between education and green growth in BRICS countries. *Journal of the Knowledge Economy*, *16*(1), 1109-1128. https://doi.org/10.1007/s13132-024-01948-3

Solaymani, S., & Montes, O. (2024). The role of financial development and good governance in economic growth and environmental sustainability. *Energy Nexus*, *13*, 100268. https://doi.org/10.1016/j.nexus.2023.100268

Sun, X., Meng, Z., Zhang, X., & Wu, J. (2025). The role of institutional quality in the nexus between green financing and sustainable development. *Research in International Business and Finance*, *73*, 102531. https://doi.org/10.1016/j.ribaf.2024.102531

Tawiah, V., Zakari, A., & Adedoyin, F. F. (2021). Determinants of green growth in developed and developing countries. *Environmental Science and Pollution Research*, *28*(29), 39227-39242. https://doi.org/10.1007/s11356-021-13429-0

Wang, N., Ullah, A., Lin, X., Zhang, T., & Mao, J. (2022). Dynamic influence of urbanization on inclusive green growth in belt and road countries: the moderating role of governance. *Sustainability*, *14*(18), 11623. https://doi.org/10.3390/su141811623