

Green Growth in OIC Countries: Symmetric and Asymmetric Dynamics of Institutions, Finance, and Environmental Technology

Aninta Gina Sharfina *

UIN Sunan Kalijaga Yogyakarta, Indonesia

Corresponding Email: aninta.sharfina@uin-suka.ac.id

Abstract

Green growth seeks to reconcile economic expansion with the preservation of natural resources essential for future development. However, the factors shaping green growth in member countries of the Organization of Islamic Cooperation (OIC) remain insufficiently understood. This study investigates the relationship between institutional quality, financial development, environmental technology, and green growth in Indonesia, Malaysia, Egypt, Uganda, Tunisia, Bangladesh, and Nigeria over the period 2002–2020. Using 133 country-year observations, the analysis employs linear and nonlinear panel autoregressive distributed lag (ARDL and NARDL) models, with the Hausman test results supporting the use of the pooled mean group (PMG) estimator. The findings identify environmental technology as the factor most strongly associated with green growth, exhibiting a positive long-run relationship but a negative short-run effect. The nonlinear estimates further suggest that this long-run relationship is driven primarily by periods of declining environmental innovation. Institutional quality is positively associated with green growth in the long run, while institutional deterioration appears to offset gains of a comparable magnitude. Financial development, by contrast, shows no significant long-run benefit and is negatively associated with green growth in the short run. However, as the equality of coefficients associated with positive and negative changes was not formally tested, the estimated asymmetries should be interpreted as indicative rather than conclusive. These findings highlight the importance of strengthening institutional capacity, aligning financial resources with green investment priorities, and maintaining stable support for environmental innovation.

Keywords: *Green Growth, Institutional Quality, Financial Development, Environment-Related Technology, and Panel NARDL.*

JEL Classification: *C33, O16, O43, and Q56.*

 <https://doi.org/10.14710/jdep.7.1.70-86>



[This is an open-access article under the CC BY-SA 4.0 license](#)

Introduction

Green growth seeks to reconcile economic development with environmental sustainability by using resources more efficiently, protecting natural capital, and creating new economic opportunities (OECD, 2011). Unlike conventional output measures, it asks whether growth can last without eroding the environmental base that future development depends on (Acosta et al., 2020; OECD, 2011). Three conditions shape this outcome. Institutions determine how environmental policies are designed and enforced (Kaufmann et al., 2010; Tamazian & Rao, 2010), financial systems

*Corresponding Author: Aninta Gina Sharfina, UIN Sunan Kalijaga Yogyakarta, Jl. Laksda Adisucipto, Papringan, Caturtunggal, Depok, Sleman, Indonesia, aninta.sharfina@uin-suka.ac.id

decide where capital flows (Shahbaz et al., 2016), and environment-related technology enables cleaner, more efficient production (Danish & Ulucak, 2020). Yang et al. (2024) examine these factors together and find that digital technologies, financial development, and institutional quality all support long-run green growth in South Asia.

Evidence on institutions is largely positive. Institutional quality supports long-run green growth in South Asia (Ahmed et al., 2022) and is positively associated with green gross domestic product (GDP) in member countries of the Organisation of Islamic Cooperation (OIC) (Ali & Lacheheb, 2023). The OIC study, however, covers only 2016–2019. Evidence on finance is mixed, because credit can fund clean investment as easily as polluting activity (Tamazian & Rao, 2010; Zakaria & Bibi, 2019). Ahmed et al. (2022) find that financial development raises green growth in South Asia, whereas Ali and Lacheheb (2023) find that it lowers green GDP in OIC countries.

Technology also needs a precise definition. Yang et al. (2024) study digital technologies, while Awodumi et al. (2025) show that general and green innovation affect green growth differently across ten developing and transition economies. This study therefore focuses on environment-related technology. These studies differ in region and variables. Two cover South Asia (Ahmed et al., 2022; Yang et al., 2024), one uses green GDP for OIC countries (Ali & Lacheheb, 2023), and one covers non-OIC developing and transition economies (Awodumi et al., 2025). None examines institutions, finance, and environmental technology together against a multidimensional green growth index for OIC countries in Asia and Africa.

A second gap concerns the direction of change. Linear models assume that green growth responds to an increase and a decrease of the same size in the same way. The nonlinear autoregressive distributed lag (NARDL) model relaxes this assumption by splitting each variable into cumulative increases and decreases; differing coefficients suggest asymmetry, and a formal equality test confirms it (Shin et al., 2014). This study examines how institutional quality, financial development, and environment-related technology relate to green growth in seven OIC countries (Indonesia, Malaysia, Egypt, Uganda, Tunisia, Bangladesh, and Nigeria) over 2002–2020, using the multidimensional index of Acosta et al. (2020). A linear panel autoregressive distributed lag (ARDL) model separates short-run from long-run effects, and a NARDL model compares responses to increases and decreases. Three estimators are compared: mean group (MG), pooled mean group (PMG), and dynamic fixed effects (DFE) (Blackburne & Frank, 2007; Pesaran et al., 1999; Pesaran & Smith, 1995).

The study contributes in two ways. It combines the three factors and a multidimensional green growth index in one framework for OIC economies in Asia and Africa, extending work that focuses on South Asia or fewer variables (Ahmed et al., 2022; Ali & Lacheheb, 2023; Yang et al., 2024). It also separates short-run from long-run effects and responses to increases from responses to decreases, without assuming in advance that the effects are positive or asymmetric.

Literature Review

Green Growth

The OECD (2011) defines green growth as economic progress that maintains and enhances environmental assets while supporting human well-being. Measuring it requires more than income data, and studies have used approaches ranging from green

economic growth accounting in China (Song et al., 2019) and natural capital accounting in India (Islam & Managi, 2019) to a composite index of OECD indicators for Taiwan (Lee & Chou, 2018).

A broad measure matters because progress on one indicator does not ensure progress on others (Lee & Chou, 2018). Acosta et al. (2020) build an index with four dimensions: efficient and sustainable resource use, natural capital protection, green economic opportunities, and social inclusion. This breadth suits developing economies, where growth can finance environmental investment but can also accelerate resource extraction (OECD, 2011). This study uses the Acosta et al. (2020) index.

Institutional Quality and Green Growth

Institutions govern how policy is made, implemented, and enforced, and they are a fundamental cause of long-run economic performance (Acemoglu et al., 2005). Kaufmann et al. (2010) measure governance in six dimensions: voice and accountability, political stability, government effectiveness, regulatory quality, rule of law, and control of corruption.

These dimensions also shape environmental outcomes. Democracy improves air quality (Bernauer & Koubi, 2009), governance quality and democratic development drive environmental performance (Dluhopolskyi et al., 2019), and e-government and control of corruption are linked to better environmental performance (Rodríguez-Martínez et al., 2019). The effect still depends on the institutional framework in which economic policy operates (Tamazian & Rao, 2010). Because rules and enforcement change slowly, institutions are expected to affect green growth mainly in the long run (Acemoglu et al., 2005).

H₁: Institutional quality is positively associated with green growth in the long run.

Financial Development and Green Growth

Financial development affects green growth through the volume and direction of capital. Deeper financial systems ease access to funding for clean technologies, but they also finance resource-intensive industries and raise energy demand (Sadorsky, 2010). Financial liberalisation harms the environment in transition economies unless strong institutions are in place (Tamazian & Rao, 2010), and bank-based financial development worsens environmental quality in Pakistan (Shahbaz et al., 2016).

Country studies show that the effect varies. Financial development has no significant long-run effect on carbon emissions in Turkey (Ozturk & Acaravci, 2013) but follows an inverted U-shape in the United Arab Emirates, where emissions first rise and then fall as finance deepens (Charfeddine & Khediri, 2016). In a composite index, these opposing forces may partly cancel out. A financial system that allocates capital efficiently, however, can support the shift to a greener economy (Ahmed et al., 2022; Campiglio, 2016).

H₂: Financial development is positively associated with green growth.

Environment-Related Technology and Green Growth

Environment-related technology supports green growth by raising resource efficiency and cutting pollution per unit of output (OECD, 2011), provided that firms adopt it (Jaffe et al., 2002). It raises green growth in the BRICS economies (Brazil, Russia, India, China, and South Africa) (Danish & Ulucak, 2020), but the type of technology matters. In OECD countries, transport and production technologies support green growth in some regions while energy-generation technologies undermine it (Mensah et al., 2019); in the European Union, the pattern is reversed (Nosheen et al., 2021).

Invention alone is not enough. New technologies diffuse gradually, and diffusion stalls where financing, infrastructure, or institutional capacity is weak (Awodumi et al., 2025; Jaffe et al., 2002). The long-run relationship is expected to be positive, but its size may depend on each country's capacity to adopt.

H₃: Environment-related technological innovation is positively associated with green growth in the long run.

Increases and Decreases: The Case for a Nonlinear Model

Green growth may respond differently to gains and losses. Institutional reform need not mirror institutional decline, credit expansion and contraction may affect different industries, and a fall in innovation may hurt more than a rise helps. The NARDL model captures these possibilities by giving cumulative increases and decreases their own short-run and long-run coefficients (Shin et al., 2014).

Each variable offers a specific mechanism. Institutional improvement is slow, because credible rules and enforcement capacity build up gradually (North, 1990). Deterioration acts faster: weaker control of corruption lets firms evade environmental regulation at once, and instability raises policy uncertainty, which delays irreversible green investment (Bernanke, 1983; Dixit & Pindyck, 1994). Institutional decline may therefore reduce green growth faster or more strongly than an equal improvement raises it.

For finance, new credit tends to flow first to established, collateral-rich firms that are often energy intensive, and it raises energy demand (Sadorsky, 2010), while riskier, longer-maturity green projects are rationed (Campiglio, 2016; Stiglitz & Weiss, 1981). Expansion may therefore add little to green growth unless institutions redirect credit (Tamazian & Rao, 2010). Contraction spreads quickly through firms' balance sheets (Bernanke et al., 1999) and immediately shrinks credit-financed, energy-intensive activity, so its effect need not mirror that of expansion, just as positive and negative monetary shocks have unequal effects (Cover, 1992).

For environmental technology, a rise in innovation helps only after it diffuses, and diffusion depends on absorptive capacity, finance, and infrastructure (Cohen & Levinthal, 1990; Jaffe et al., 2002), so gains build up slowly. A fall works through path dependence: because innovation builds on the existing knowledge stock, declining clean innovation shifts research back towards polluting technologies (Acemoglu et al., 2012; Aghion et al., 2016), a shift reinforced by carbon lock-in (Unruh, 2000). A decline in environmental innovation may therefore reduce green growth by more than an equal increase raises it.

Sohag et al. (2019) use this approach for green economic growth in Turkey and find asymmetric long-run effects of cleaner energy, technological innovation, and militarisation. This study applies it to institutions, finance, and technology in OIC

countries. Differing coefficients indicate asymmetry; an equality test is needed to confirm it (Shin et al., 2014).

H₄: Green growth may respond differently to positive and negative changes in institutional quality, financial development, and environment-related technological innovation.

Research Methodology

Data, Sample, and Variables

The study examines seven OIC countries: Indonesia, Malaysia, Egypt, Uganda, Tunisia, Bangladesh, and Nigeria, using annual data from 2002 to 2020. The balanced panel comprises 133 observations, with no imputation of missing data.

The seven countries were selected on empirical and theoretical grounds. Empirically, they are the OIC members with complete annual data on all four variables for 2002–2020. A balanced panel is required because PMG estimates each country's short-run dynamics from its own time series (Pesaran et al., 1999) and the partial sums in Equation (3) accumulate changes year by year (Shin et al., 2014). Theoretically, the sample provides the variation that the research questions require. It covers Southeast Asia, South Asia, North Africa, and Sub-Saharan Africa, ranges from low income (Uganda) to upper-middle income (Malaysia) (World Bank, 2021), and differs widely in institutional quality (Figure 1), which suits the PMG test of common long-run coefficients across heterogeneous countries. It also contains movements in both directions, such as institutional improvement in Indonesia and deterioration in Egypt after 2011 (Figure 1), without which the positive and negative NARDL components could not be estimated separately (Shin et al., 2014). The results therefore apply to these seven countries rather than to all 57 OIC members.

Table 1. Variables, Measurement, and Sources

Variable	Symbol	Measurement	Scale	Source
Green growth	GG	Green Growth Index: 36 indicators in four dimensions (resource efficiency, natural capital protection, green economic opportunities, social inclusion)	Transformed index	Acosta et al. (2020)
Institutional quality	IQ	Mean of six WGI dimensions (voice and accountability, political stability, government effectiveness, regulatory quality, rule of law, control of corruption), each standardised over the pooled panel	Index, mean 0	World Bank WGI; Kaufmann et al. (2010)
Financial development	FD	Depth, access, and efficiency of financial institutions and markets	0–1	IMF; Svirydzienka (2016)
Environment-related technology	GT	Development, diffusion, and international collaboration in environment-related inventions	Index	OECD

Note: annual data, 2002–2020. WGI = Worldwide Governance Indicators; IMF = International Monetary Fund; OECD = Organisation for Economic Co-operation and Development. Source: compiled by the author (2022).

Table 1 defines the variables. Green growth (GG) is the Green Growth Index of the Global Green Growth Institute (Acosta et al., 2020), which combines 36 indicators in four dimensions and enters the model on a transformed scale from -1.281 to 0.856 . Institutional quality (IQ) is measured as the average of the six Worldwide Governance Indicators (WGI) (Kaufmann et al., 2010), standardised across the 133 observations. Financial development (FD) is measured using the IMF Financial Development Index (Sviryzdenka, 2016). Environment related technology (GT) is based on OECD indicators covering the development, diffusion, and international co invention of environmental technologies.

Linear Panel ARDL

The long-run relationship is:

$$GG_{it} = \alpha_i + \beta_1 IQ_{it} + \beta_2 FD_{it} + \beta_3 GT_{it} + \varepsilon_{it} \quad (1)$$

where i is the country, t the year, α_i a country-specific intercept, β_1 to β_3 the long-run parameters, and ε_{it} the error term.

Equation (1) is estimated as a panel ARDL model. This model is valid when variables are a mix of $I(0)$, stationary in levels, and $I(1)$, stationary after first differencing, as long as none is $I(2)$ (Pesaran et al., 2001). It also separates long-run relationships from short-run adjustment and lets short-run dynamics differ across countries (Pesaran et al., 1999). In error-correction form, the ARDL(p, q) model is:

$$\begin{aligned} \Delta GG_{it} = & \phi_i (GG_{i,t-1} - \theta_1 IQ_{i,t-1} - \theta_2 FD_{i,t-1} - \theta_3 GT_{i,t-1}) + \sum_{j=1}^{p-1} \lambda_{ij} \Delta GG_{i,t-j} \\ & + \sum_{j=0}^{q-1} (\alpha_{ij} \Delta IQ_{i,t-j} + \gamma_{ij} \Delta FD_{i,t-j} + \delta_{ij} \Delta GT_{i,t-j}) + \mu_i + \varepsilon_{it} \end{aligned} \quad (2)$$

where Δ is the first-difference operator, p and q are lag orders, θ_1 to θ_3 are long-run coefficients, λ_{ij} , α_{ij} , γ_{ij} , and δ_{ij} are short-run coefficients, and μ_i is a country effect. ϕ_i is the speed of adjustment to the long-run path; a negative and significant ϕ_i confirms a long-run relationship (Pesaran et al., 1999).

The estimators differ in how much they pool across countries. MG estimates each country separately and averages the coefficients (Pesaran & Smith, 1995). PMG holds the long-run coefficients equal across countries but lets short-run coefficients, adjustment speeds, and intercepts vary (Pesaran et al., 1999). DFE holds slopes and adjustment speeds equal and lets only intercepts vary (Blackburne & Frank, 2007).

Nonlinear Panel ARDL

The NARDL model of Shin et al. (2014) splits each variable $X \in \{IQ, FD, GT\}$ into cumulative increases and cumulative decreases:

$$X_{it}^+ = \sum_{s=1}^t \max(\Delta X_{is}, 0), \quad X_{it}^- = \sum_{s=1}^t \min(\Delta X_{is}, 0) \quad (3)$$

so that X^- is always zero or negative. Replacing each variable in Equation (2) with its two components gives:

$$\Delta G G_{it} = \phi_i \left(G G_{i,t-1} - \sum_{k=1}^3 [\theta_k^+ X_{k,i,t-1}^+ + \theta_k^- X_{k,i,t-1}^-] \right) + \sum_{j=1}^{p-1} \lambda_{ij} \Delta G G_{i,t-j} + \sum_{k=1}^3 \sum_{j=0}^{q-1} (\pi_{kij}^+ \Delta X_{k,i,t-j}^+ + \pi_{kij}^- \Delta X_{k,i,t-j}^-) + \mu_i + \varepsilon_{it} \quad (4)$$

where θ_k^+ and θ_k^- are the long-run coefficients on increases and decreases, and π_{kij}^+ and π_{kij}^- are the short-run ones. Because X^- is non-positive, a positive θ^- means that a fall in X lowers green growth, and a negative θ^- means that it raises green growth.

Long-run asymmetry is confirmed when a Wald test rejects equal coefficients (Shin et al., 2014):

$$H_0: \theta_X^+ = \theta_X^- \quad \text{against} \quad H_1: \theta_X^+ \neq \theta_X^- \quad (5)$$

This test was not performed, so Section 4 treats differences between θ^+ and θ^- as indicative, not confirmed.

Estimation Procedure and Preliminary Tests

The analysis begins with descriptive statistics and Pearson correlation coefficients. Panel unit root tests are then used to establish that none of the variables is integrated of order two, $I(2)$. Three tests are applied: Breitung (2000), which assumes a common unit root process; the Im, Pesaran, and Shin (IPS) test (Im et al., 2003), which allows for country specific coefficients; and the Fisher augmented Dickey Fuller (Fisher ADF) test (Maddala & Wu, 1999), which combines individual country test results. For each test, the null hypothesis of a unit root is assessed in both levels and first differences.

Third, both models are estimated with MG, PMG, and DFE, and the Hausman (1978) test selects among them:

$$H = (\hat{\beta}_A - \hat{\beta}_B)' [\hat{V}_A - \hat{V}_B]^{-1} (\hat{\beta}_A - \hat{\beta}_B) \quad (6)$$

where $\beta^$ is the vector of long-run coefficients and $V^$ its covariance matrix. MG (A) is always consistent; PMG (B) is more efficient when long-run coefficients are homogeneous (Pesaran et al., 1999). H follows a χ^2 distribution. If the null is not rejected, PMG is preferred and then tested against DFE (Blackburne & Frank, 2007). Fourth, the preferred estimates are interpreted by sign, significance, and horizon, with MG and DFE kept for comparison. Estimation uses Stata 13.

Results and Discussion

Institutional Quality across the Sample

Figure 1 shows substantial differences in institutional quality across the sample. Malaysia records the highest average score (1.52), followed by Tunisia (0.59), while Nigeria (−1.04) and Bangladesh (−0.68) have the lowest. Institutional quality also follows different trajectories over time. Indonesia's score improves from −0.53 in 2002 to 0.73 in 2020, whereas Egypt's declines from 0.02 to −0.67, particularly after 2011.

These contrasting trends provide a basis for examining whether improvements and declines in institutional quality have different effects on green growth.

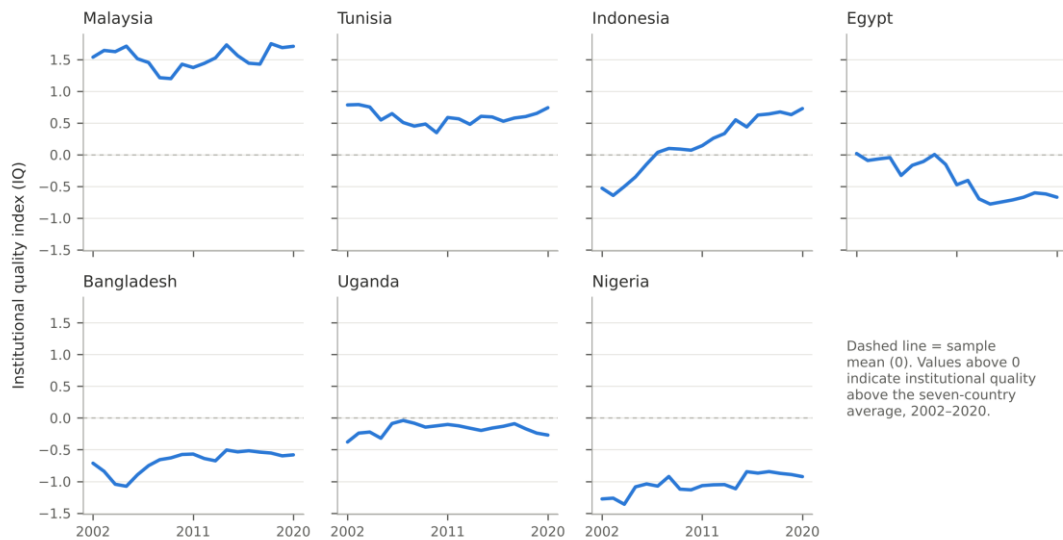


Figure 1. Institutional Quality Index (IQ) by Country, 2002–2020.

The index averages six WGI dimensions, each standardised over the 133 pooled observations; the dashed line marks the sample mean (0). Source: World Bank WGI, processed by the author

Green growth (GG) has a mean of 0.008 and a standard deviation of 0.409, while institutional quality (IQ) has a mean of zero by construction (Table 2). Financial development (FD) averages 0.267 on a scale of 0 to 1, with a maximum of 0.663. Environmental technology is the only variable significantly correlated with GG ($r = 0.312$, $p < 0.01$). The correlations between GG and both IQ and FD are weak, although their effects may emerge over time. IQ and FD, by contrast, are strongly correlated ($r = 0.743$). While below the 0.80 threshold commonly used to indicate potential multicollinearity (Gujarati & Porter, 2009), this correlation warrants caution when interpreting their individual effects. Zakaria and Bibi (2019) report a similar link between financial development and institutional quality in South Asia.

Table 2. Descriptive Statistics and Pearson Correlations

Variable	Mean	Std. dev.	Min	Max	GG	IQ	FD	GT
GG	0.008	0.409	-1.281	0.856	1.000			
IQ	0.000	0.830	-1.360	1.749	-0.016	1.000		
FD	0.267	0.169	0.000	0.663	-0.007	0.743***	1.000	
GT	-0.002	0.345	-0.500	0.610	0.312***	0.047	0.117	1.000

Note: 133 observations for each variable. *** $p < 0.01$. Correlations describe linear co-movement only. Source: author's calculations (2022).

This study extends the existing literature by examining institutional quality, financial development, and environment-related technology jointly in seven OIC countries across Asia and Africa, using a multidimensional green growth index. It also distinguishes short-run from long-run effects and examines whether increases and decreases in these factors are associated with different green growth outcomes. This

approach goes beyond studies that focus on a single region, use fewer explanatory variables, or rely on linear models.

Table 3. Panel Unit-Root Tests

Variable	Test	Level	First difference	Order
GG	Breitung	-3.716*** (< 0.001)	-2.949*** (0.002)	I(0)/I(1)
	IPS	-1.593* (0.056)	-5.596*** (< 0.001)	
	Fisher-ADF	19.888 (0.134)	73.383*** (< 0.001)	
IQ	Breitung	0.228 (0.590)	-3.141*** (< 0.001)	I(1)
	IPS	-1.018 (0.154)	-4.901*** (< 0.001)	
	Fisher-ADF	16.385 (0.290)	62.382*** (< 0.001)	
FD	Breitung	0.430 (0.667)	-4.506*** (< 0.001)	I(1)
	IPS	0.760 (0.777)	-4.248*** (< 0.001)	
	Fisher-ADF	9.325 (0.810)	51.621*** (< 0.001)	
GT	Breitung	-2.538*** (0.006)	-3.080*** (0.001)	I(0)
	IPS	-1.662** (0.048)	-6.734*** (< 0.001)	
	Fisher-ADF	23.158* (0.058)	95.901*** (< 0.001)	

Note: p-values in parentheses. Null hypothesis: the series contains a unit root. IPS = Im, Pesaran, and Shin; Fisher-ADF = Fisher-type augmented Dickey–Fuller. Breitung and IPS statistics are standard normal; Fisher-ADF statistics are χ^2 with 14 degrees of freedom. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$. Source: author's calculations (2022).

The unit root tests show that IQ and FD are nonstationary in levels but become stationary after first differencing, indicating that both are I(1) (Table 3). GT is stationary in levels, indicating that it is I(0). The results for GG are mixed: Breitung and IPS indicate stationarity in levels, whereas Fisher ADF does not ($p = 0.134$). All variables are stationary after first differencing, and none is I(2). As Pesaran et al. (2001) explain, the ARDL approach accommodates variables with different orders of integration, provided none is I(2). This allows the study to examine short-run and long-run relationships within the same model. The study extends this approach by combining linear ARDL and nonlinear ARDL to assess whether institutional quality, financial development, and environmental technology relate to green growth differently across short- and long-run horizons and in response to increases and decreases in these factors in OIC countries.

Linear Panel ARDL Estimates

The Hausman test results support the use of the pooled mean group (PMG) estimator (Table 4). The test does not reject the equality of long-run coefficients between mean group (MG) and PMG ($p = 0.934$). The comparison between PMG and dynamic fixed effects (DFE) also shows no significant difference ($p = 0.950$). PMG is therefore used as the main estimator because it allows countries to share common long-run coefficients while retaining country-specific short-run dynamics (Pesaran et al., 1999). This is suitable for the sample, which includes countries with different levels of economic and institutional development.

Table 4. Linear Panel ARDL Estimates (Dependent Variable: GG)

Variable	MG	PMG	DFE
<i>Long run</i>			
IQ	0.175 (0.800)	0.334* (0.051)	-0.189 (0.529)
FD	0.141 (0.696)	0.123 (0.701)	0.621* (0.096)
GT	1.262*** (< 0.001)	1.278*** (< 0.001)	1.012*** (< 0.001)
<i>Short run</i>			
Δ IQ	-0.089 (0.812)	-0.005 (0.986)	0.164 (0.544)
Δ FD	negative ^a *** (0.006)	negative ^a *** (0.005)	negative ^a *** (< 0.001)
Δ GT	-0.272*** (0.004)	-0.272*** (< 0.001)	-0.195** (0.049)
<i>Hausman test, χ^2 (p-value)</i>			
MG vs PMG		0.08 (0.934)	
PMG vs DFE			0.35 (0.950)
Observations	133	133	133

Note: p-values in parentheses. MG = mean group; PMG = pooled mean group; DFE = dynamic fixed effects. Hausman null hypothesis: no systematic difference in the long-run coefficients. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$. ^a Only the sign and significance of this coefficient are reported. Source: author's estimation (2022).

Environmental technology (GT) shows the strongest and most consistent relationship with green growth. Its long-run coefficient is positive and significant under all three estimators, ranging from 1.012 to 1.278. The PMG estimate indicates that a one unit increase in GT is associated with a 1.278 unit increase in GG in the long run. This finding is consistent with Danish and Ulucak (2020), who report a positive relationship between environmental technology and green growth in BRICS economies. However, the short-run coefficient is negative and significant (-0.272), suggesting that the benefits of environmental technology may take time to emerge. Investment in new technologies, equipment, and worker training can involve initial costs before improvements in resource efficiency become apparent (Jaffe et al., 2002). The findings also highlight the importance of technological context, as Mensah et al. (2019) show that the effects of different environmental technologies on green growth vary across OECD countries.

The relationship between institutional quality (IQ) and green growth is less conclusive in the linear model. The PMG coefficient is positive (0.334) but only marginally significant at the 10% level ($p = 0.051$), while the MG and DFE estimates are insignificant. None of the estimators identifies a significant short-run effect. This pattern is consistent with the view that institutions influence environmental and economic outcomes through gradual changes in policy implementation and enforcement (Acemoglu et al., 2005). The positive long-run relationship also accords with Stoeber (2012), who links institutional quality to sustainability measured by adjusted net savings, and Salman et al. (2019), who examine its relationship with economic growth and carbon emissions in Indonesia, South Korea, and Thailand. The relatively weak linear estimate suggests that the institutional effect may be more complex than a single coefficient can capture, an issue examined further through the nonlinear model.

Financial development (FD) shows no statistically significant long-run relationship with green growth under MG and PMG, although the DFE estimate is weakly positive ($p = 0.096$). In the short run, its coefficient is negative and significant

under all three estimators. This suggests that financial expansion does not automatically translate into greener economic activity. Credit may continue to support established industries and energy-intensive production rather than cleaner investment, consistent with Sadorsky (2010) and Shahbaz et al. (2016). Zakaria and Bibi (2019) similarly highlight the role of institutional quality in shaping the environmental implications of financial development in South Asia. Tamazian and Rao (2010) also show that the environmental effects of financial development depend on institutional conditions. These studies help explain why greater financial development may not improve green growth when credit allocation is not aligned with environmental priorities. The absence of a significant long-run effect in the PMG model suggests that financial development alone is insufficient to support green growth in the countries examined.

Taken together, the linear estimates reveal distinct patterns across the three explanatory variables: environmental technology has a positive long-run but negative short-run relationship with green growth, institutional quality has a weak positive long-run association, and financial development has no significant long-run effect and a negative short-run relationship. The contribution of this study lies in examining these factors jointly using a multidimensional green growth index across seven OIC countries in Asia and Africa. By combining linear and nonlinear panel ARDL models, the analysis also investigates whether the relationships differ between the short and long run and between increases and decreases in each factor. This provides a more detailed account of the dynamics of green growth than studies focused on a single region, a narrower set of explanatory variables, or linear relationships alone.

Nonlinear Panel ARDL Estimates

The Hausman tests support the PMG estimator for the nonlinear model (MG vs PMG: $p = 0.997$; PMG vs DFE: $p = 0.989$). The results show that green growth relates differently to changes in institutional quality, financial development, and environmental technology (Table 5). Institutional quality has a positive and significant long-run coefficient for both increases ($IQ^+ = 0.919$, $p < 0.01$) and decreases ($IQ^- = 0.988$, $p < 0.01$). This suggests that institutional improvements are associated with higher green growth, while institutional deterioration is associated with lower green growth. Neither component has a significant short-run effect. These findings are consistent with Stoeber (2012) and Salman et al. (2019), who link institutional quality to sustainability and environmental outcomes. The nonlinear estimates also show a stronger long-run relationship than the linear model, although the difference between the two coefficients has not been formally tested. The similar size of IQ^+ and IQ^- suggests that the uncertainty channel described in Section 2.5 is not strong enough here to make decline costlier than improvement.

Financial development shows no significant long-run relationship with green growth when it increases ($FD^+ = -0.371$, $p = 0.336$). By contrast, decreases have a significant negative coefficient ($FD^- = -1.457$, $p = 0.007$). Since FD^- captures declines, this result indicates that falling financial development is associated with higher green growth. It does not mean that financial contraction necessarily improves environmental outcomes. Rather, financial expansion may not be directed towards green investment. This interpretation is consistent with Tamazian and Rao (2010), who show that institutional conditions shape the environmental effects of financial

development, and Zakaria and Bibi (2019), who highlight the role of institutional quality in the finance environment relationship in South Asia. This fits the credit-allocation mechanism in Section 2.5.

Table 5. PMG Estimates of the Nonlinear Panel ARDL Model
(Dependent Variable: GG)

Variable	Long run	Short run
IQ ⁺	0.919*** (< 0.001)	-0.203 (0.748)
IQ ⁻	0.988*** (< 0.001)	0.106 (0.821)
FD ⁺	-0.371 (0.336)	0.804 (0.363)
FD ⁻	-1.457*** (0.007)	1.987 (0.237)
GT ⁺	-0.410 (0.102)	-0.040 (0.555)
GT ⁻	5.654*** (< 0.001)	-1.248*** (0.002)
Observations	133	

Note: p-values in parentheses. *** $p < 0.01$. X^+ and X^- are cumulative sums of positive and negative changes; $X^- \leq 0$, so a positive coefficient on X^- means that declines in X go with lower GG. Hausman tests: MG vs PMG $\chi^2 = 0.53$ ($p = 0.997$); PMG vs DFE $\chi^2 = 0.92$ ($p = 0.989$). Wald tests of coefficient equality were not carried out. Source: author's estimation (2022).

Environmental technology also shows different results for increases and decreases. The coefficient for increases is negative but insignificant ($GT^+ = -0.410$, $p = 0.102$), while the coefficient for decreases is positive and significant ($GT^- = 5.654$, $p < 0.01$). Because GT^- captures declines in environmental technology, the positive coefficient indicates that falling innovation is associated with lower green growth. Thus, the positive long-run relationship found in the linear model appears to reflect the consequences of declining innovation rather than a significant effect of increasing innovation. This finding highlights the importance of maintaining technological capacity and supports the argument of Jaffe et al. (2002) that innovation requires time and complementary investment to improve environmental performance. It also fits the path-dependence mechanism in Section 2.5.

In the short run, only the coefficient for declining environmental technology is significant ($GT^- = -1.248$, $p = 0.002$). Its negative sign indicates a temporary positive association between falling innovation and green growth. This differs from the long-run result and should be interpreted cautiously, particularly because the estimated long-run coefficient is large relative to the observed range of green growth. Overall, institutional quality is positively associated with green growth in both directions of change, while the significant long-run relationships for financial development and environmental technology are concentrated in periods of decline. A related pattern was reported by Sohag et al. (2019) for green economic growth in Turkey. This study extends previous research by examining all three factors within a single framework, using a multidimensional green growth index for seven OIC countries in Asia and Africa. It also distinguishes short-run from long-run relationships and separates increases from decreases in each factor. These features provide a broader account of green growth dynamics than studies focusing on a single factor or region. However, because the equality of the positive and negative coefficients was not formally tested, the results indicate potential asymmetry rather than confirm it. Table 6 summarises the findings in relation to the research hypotheses.

Table 6. Summary of Findings and Hypotheses

Hypothesis	Linear ARDL (PMG)	Nonlinear ARDL (PMG)	Decision
H1: Institutional quality → green growth (positive, long run)	Long run: 0.334* ($p = 0.051$); short run: not significant	IQ^+ : 0.919***; IQ^- : 0.988***; short run: not significant	Supported (marginal in the linear model, strong in the nonlinear model)
H2: Financial development → green growth (positive)	Long run: 0.123 (n.s.); short run: negative***	FD^+ : -0.371 (n.s.); FD^- : -1.457*** (contraction associated with higher GG)	Not supported
H3: Environment-related technology → green growth (positive, long run)	Long run: 1.278***; short run: -0.272***	GT^+ : -0.410 (n.s.); GT^- : 5.654*** (decline associated with lower GG); short run GT^- : -1.248***	Supported; the long-run association is driven by declines
H4: Different responses to increases and decreases	Not applicable (symmetry imposed)	IQ : nearly equal coefficients; FD and GT : significant only for decreases	Partially supported (indicative; Wald test not performed)

Note: *** $p < 0.01$; * $p < 0.10$; n.s. = not significant at the 10% level. X^+ and X^- are cumulative increases and decreases. Because $X^- \leq 0$, a positive coefficient on X^- means that declines in X are associated with lower GG, and a negative coefficient means that declines are associated with higher GG. The equality of the X^+ and X^- coefficients was not tested with a Wald test. Source: summarised from Tables 4 and 5 (2022).

The nonlinear results provide partial support for H4. Institutional quality shows similar long-run effects when it rises or falls, with coefficients of 0.919 and 0.988. This suggests a broadly balanced relationship with green growth. Financial development and environmental technology show a more distinct pattern, with their long-run effects mainly linked to changes in the declining direction. This pattern fits the asymmetric adjustment that the NARDL model is designed to detect (Shin et al., 2014) and is similar to what Sohag et al. (2019) found for green economic growth in Turkey. Because a significant and a non-significant coefficient are not necessarily different from each other (Gelman & Stern, 2006), a Wald test is still needed to confirm the asymmetry. Even so, the results show where asymmetry is most likely to appear, namely in how green growth responds when financial development and environmental innovation decline.

Conclusion

This study examined the relationships between institutional quality, financial development, environmental technology, and green growth in seven OIC countries from 2002 to 2020 using linear and nonlinear panel ARDL models. Three findings emerge. First, institutional quality supports green growth in the long run, with improvements and declines showing effects of similar magnitude. Second, financial development has not yet translated into higher green growth, with no significant long-run effect and a negative short-run relationship. Third, environmental technology has the strongest long-run relationship with green growth. Its short-run effect is negative, while declines in environmental innovation are associated with lower green growth in the long run. These results show that the contribution of institutions, finance, and technology depends on the time horizon and the direction of change.

The findings point to three policy priorities. Governments need to maintain institutional capacity and policy enforcement, particularly during periods of institutional change. Financial authorities should encourage credit allocation towards green investment through appropriate lending guidelines. Continued support for environmental research and innovation is also important, while targeted assistance can help firms manage the initial costs of adopting new technologies (Campiglio, 2016; Jaffe et al., 2002). The study provides a basis for further research on green growth in OIC countries. Future studies can extend the country coverage and observation period, examine country-specific dynamics in greater detail, and formally test the asymmetric relationships identified here. Further analysis of different types of environmental technology and methods that account for cross-country dependence could also provide deeper insight into the sources of green growth.

References

- Acemoglu, D., Aghion, P., Bursztyn, L., & Hemous, D. (2012). The environment and directed technical change. *American Economic Review*, 102(1), 131–166. <https://doi.org/10.1257/aer.102.1.131>
- Acemoglu, D., Johnson, S., & Robinson, J. A. (2005). Institutions as a fundamental cause of long-run growth. In P. Aghion & S. N. Durlauf (Eds.), *Handbook of economic growth* (Vol. 1A, pp. 385–472). Elsevier. [https://doi.org/10.1016/S1574-0684\(05\)01006-3](https://doi.org/10.1016/S1574-0684(05)01006-3)
- Acosta, L. A., Zabrocki, S., Eugenio, J. R., Sabado, R., Jr., Gerrard, S. P., Nazareth, M., & Luchtenbelt, H. G. H. (2020). *Green growth index 2020: Measuring performance in achieving SDG targets* (GGGI Technical Report No. 16). Global Green Growth Institute.
- Aghion, P., Dechezleprêtre, A., Hémous, D., Martin, R., & Van Reenen, J. (2016). Carbon taxes, path dependency, and directed technical change: Evidence from the auto industry. *Journal of Political Economy*, 124(1), 1–51. <https://doi.org/10.1086/684581>
- 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>
- Ali, Z. O. S., & Lacheheb, Z. (2023). The nonlinear impact of financial development and institutions quality on green GDP: A case study of OIC countries. *International Journal of Academic Research in Economics and Management Sciences*, 12(3), 282–298. <https://doi.org/10.6007/IJAREMS/v12-i3/19079>
- Awodumi, O. B., Adeosun, O., & Olasehinde, N. (2025). Technological innovation, green innovation and green growth in developing and transition economies: Any role for institutional quality? *SN Business & Economics*, 5(10), Article 155. <https://doi.org/10.1007/s43546-025-00926-4>
- Bernanke, B. S. (1983). Irreversibility, uncertainty, and cyclical investment. *The Quarterly Journal of Economics*, 98(1), 85–106. <https://doi.org/10.2307/1885568>
- Bernanke, B. S., Gertler, M., & Gilchrist, S. (1999). The financial accelerator in a quantitative business cycle framework. In J. B. Taylor & M. Woodford (Eds.),

- Handbook of macroeconomics* (Vol. 1C, pp. 1341–1393). Elsevier.
[https://doi.org/10.1016/S1574-0048\(99\)10034-X](https://doi.org/10.1016/S1574-0048(99)10034-X)
- Bernauer, T., & Koubi, V. (2009). Effects of political institutions on air quality. *Ecological Economics*, 68(5), 1355–1365.
<https://doi.org/10.1016/j.ecolecon.2008.09.003>
- Blackburne, E. F., & Frank, M. W. (2007). Estimation of nonstationary heterogeneous panels. *The Stata Journal*, 7(2), 197–208.
<https://doi.org/10.1177/1536867X0700700204>
- Breitung, J. (2000). The local power of some unit root tests for panel data. In B. H. Baltagi (Ed.), *Nonstationary panels, panel cointegration, and dynamic panels* (Advances in Econometrics, Vol. 15, pp. 161–177). JAI Press.
[https://doi.org/10.1016/S0731-9053\(00\)15006-6](https://doi.org/10.1016/S0731-9053(00)15006-6)
- Campiglio, E. (2016). Beyond carbon pricing: The role of banking and monetary policy in financing the transition to a low-carbon economy. *Ecological Economics*, 121, 220–230. <https://doi.org/10.1016/j.ecolecon.2015.03.020>
- Charfeddine, L., & Khediri, K. B. (2016). Financial development and environmental quality in UAE: Cointegration with structural breaks. *Renewable and Sustainable Energy Reviews*, 55, 1322–1335.
<https://doi.org/10.1016/j.rser.2015.07.059>
- Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, 35(1), 128–152.
<https://doi.org/10.2307/2393553>
- Cover, J. P. (1992). Asymmetric effects of positive and negative money-supply shocks. *The Quarterly Journal of Economics*, 107(4), 1261–1282.
<https://doi.org/10.2307/2118388>
- Danish, & Ulucak, R. (2020). How do environmental technologies affect green growth? Evidence from BRICS economies. *Science of the Total Environment*, 712, 136504. <https://doi.org/10.1016/j.scitotenv.2020.136504>
- Dixit, A. K., & Pindyck, R. S. (1994). *Investment under uncertainty*. Princeton University Press. <https://doi.org/10.1515/9781400830176>
- Dluhopolskyi, O., Koziuk, V., Ivashuk, Y., & Klapkiv, Y. (2019). Environmental welfare: Quality of policy vs. society's values. *Problemy Ekorożwoju*, 14(1), 19–28.
- Gelman, A., & Stern, H. (2006). The difference between “significant” and “not significant” is not itself statistically significant. *The American Statistician*, 60(4), 328–331. <https://doi.org/10.1198/000313006X152649>
- Gujarati, D. N., & Porter, D. C. (2009). *Basic econometrics* (5th ed.). McGraw-Hill/Irwin.
- Hausman, J. A. (1978). Specification tests in econometrics. *Econometrica*, 46(6), 1251–1271. <https://doi.org/10.2307/1913827>
- Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, 115(1), 53–74. [https://doi.org/10.1016/S0304-4076\(03\)00092-7](https://doi.org/10.1016/S0304-4076(03)00092-7)
- Islam, M., & Managi, S. (2019). Green growth and pro-environmental behavior: Sustainable resource management using natural capital accounting in India. *Resources, Conservation and Recycling*, 145, 126–138.
<https://doi.org/10.1016/j.resconrec.2019.02.027>

- Jaffe, A. B., Newell, R. G., & Stavins, R. N. (2002). Environmental policy and technological change. *Environmental and Resource Economics*, 22(1–2), 41–70. <https://doi.org/10.1023/A:1015519401088>
- Kaufmann, D., Kraay, A., & Mastruzzi, M. (2010). *The Worldwide Governance Indicators: Methodology and analytical issues* (Policy Research Working Paper No. 5430). World Bank.
- Lee, C.-M., & Chou, H.-H. (2018). Green growth in Taiwan: An application of the OECD green growth monitoring indicators. *The Singapore Economic Review*, 63(2), 249–274. <https://doi.org/10.1142/S0217590817400100>
- Maddala, G. S., & Wu, S. (1999). A comparative study of unit root tests with panel data and a new simple test. *Oxford Bulletin of Economics and Statistics*, 61(S1), 631–652. <https://doi.org/10.1111/1468-0084.0610s1631>
- Mensah, C. N., Long, X., Dauda, L., Boamah, K. B., Salman, M., Appiah-Twum, F., & Tachie, A. K. (2019). Technological innovation and green growth in the Organization for Economic Cooperation and Development economies. *Journal of Cleaner Production*, 240, 118204. <https://doi.org/10.1016/j.jclepro.2019.118204>
- North, D. C. (1990). *Institutions, institutional change and economic performance*. Cambridge University Press. <https://doi.org/10.1017/CBO9780511808678>
- Nosheen, M., Iqbal, J., & Abbasi, M. A. (2021). Do technological innovations promote green growth in the European Union? *Environmental Science and Pollution Research*, 28, 21717–21729. <https://doi.org/10.1007/s11356-020-11926-2>
- OECD. (2011). *Towards green growth*. OECD Publishing. <https://doi.org/10.1787/9789264111318-en>
- Ozturk, I., & Acaravci, A. (2013). The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. *Energy Economics*, 36, 262–267. <https://doi.org/10.1016/j.eneco.2012.08.025>
- Pesaran, M. H., Shin, Y., & Smith, R. P. (1999). Pooled mean group estimation of dynamic heterogeneous panels. *Journal of the American Statistical Association*, 94(446), 621–634. <https://doi.org/10.1080/01621459.1999.10474156>
- Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16(3), 289–326. <https://doi.org/10.1002/jae.616>
- Pesaran, M. H., & Smith, R. (1995). Estimating long-run relationships from dynamic heterogeneous panels. *Journal of Econometrics*, 68(1), 79–113. [https://doi.org/10.1016/0304-4076\(94\)01644-F](https://doi.org/10.1016/0304-4076(94)01644-F)
- Rodríguez-Martínez, C. C., García-Sánchez, I. M., Vicente-Galindo, P., & Galindo-Villardón, P. (2019). Exploring relationships between environmental performance, e-government and corruption: A multivariate perspective. *Sustainability*, 11(22), 6497. <https://doi.org/10.3390/su11226497>
- Sadorsky, P. (2010). The impact of financial development on energy consumption in emerging economies. *Energy Policy*, 38(5), 2528–2535. <https://doi.org/10.1016/j.enpol.2009.12.048>
- Salman, M., Long, X., Dauda, L., & Mensah, C. N. (2019). The impact of institutional quality on economic growth and carbon emissions: Evidence from Indonesia, South Korea and Thailand. *Journal of Cleaner Production*, 241, 118331. <https://doi.org/10.1016/j.jclepro.2019.118331>

- Shahbaz, M., Shahzad, S. J. H., Ahmad, N., & Alam, S. (2016). Financial development and environmental quality: The way forward. *Energy Policy*, 98, 353–364. <https://doi.org/10.1016/j.enpol.2016.09.002>
- Shin, Y., Yu, B., & Greenwood-Nimmo, M. (2014). Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. In R. C. Sickles & W. C. Horrace (Eds.), *Festschrift in honor of Peter Schmidt: Econometric methods and applications* (pp. 281–314). Springer New York. https://doi.org/10.1007/978-1-4899-8008-3_9
- Sohag, K., Taşkın, F. D., & Malik, M. N. (2019). Green economic growth, cleaner energy and militarization: Evidence from Turkey. *Resources Policy*, 63, 101407. <https://doi.org/10.1016/j.resourpol.2019.101407>
- Song, X., Zhou, Y., & Jia, W. (2019). How do economic openness and R&D investment affect green economic growth? Evidence from China. *Resources, Conservation and Recycling*, 146, 405–415. <https://doi.org/10.1016/j.resconrec.2019.03.050>
- Stiglitz, J. E., & Weiss, A. (1981). Credit rationing in markets with imperfect information. *The American Economic Review*, 71(3), 393–410. <https://www.jstor.org/stable/1802787>
- Stoeber, J. (2012). On comprehensive wealth, institutional quality and sustainable development: Quantifying the effect of institutional quality on sustainability. *Journal of Economic Behavior & Organization*, 81(3), 794–801. <https://doi.org/10.1016/j.jebo.2010.12.017>
- Svirydzenka, K. (2016). *Introducing a new broad-based index of financial development* (IMF Working Paper No. 16/5). International Monetary Fund. <https://doi.org/10.5089/9781513583709.001>
- 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. <https://doi.org/10.1016/j.eneco.2009.04.004>
- Unruh, G. C. (2000). Understanding carbon lock-in. *Energy Policy*, 28(12), 817–830. [https://doi.org/10.1016/S0301-4215\(00\)00070-7](https://doi.org/10.1016/S0301-4215(00)00070-7)
- World Bank. (2021). *World Bank country and lending groups*. World Bank Data Help Desk. <https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups>
- Yang, C., Qi, H., Jia, L., Wang, Y., & Huang, D. (2024). Impact of digital technologies and financial development on green growth: Role of mineral resources, institutional quality, and human development in South Asia. *Resources Policy*, 90, 104699. <https://doi.org/10.1016/j.resourpol.2024.104699>
- Zakaria, M., & Bibi, S. (2019). Financial development and environment in South Asia: The role of institutional quality. *Environmental Science and Pollution Research*, 26(8), 7926–7937. <https://doi.org/10.1007/s11356-019-04284-1>