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MODERATING ROLE OF INSTITUTIONAL QUALITY IN THE ECONOMIC GROWTH–CARBON EMISSIONS NEXUS: PANEL EVIDENCE FROM SOUTH ASIAN BRI PARTICIPANT COUNTRIES

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Abstract
Carbon emissions constitute a primary environmental problem for developing economies striving to maintain economic growth while fulfilling climate-related policy obligations. This study investigates the long-term relationship between economic growth and carbon emissions in specific South Asian nations included in the Belt and Road Initiative, focusing on the moderating influence of institutional quality. Utilising the Environmental Kuznets Curve framework, the study examines whether the relationship between per capita income and carbon emissions exhibits an inverted U-shaped trajectory and whether enhanced institutional quality mitigates the environmental costs of economic growth. Annual panel data for Pakistan, India, Bangladesh, and Sri Lanka from 1984 to 2019 are evaluated via a panel Autoregressive Distributed Lag methodology. The empirical model includes per capita income, squared per capita income, energy consumption, export diversification, foreign direct investment, technological advancement, and the interaction between per capita income and institutional quality. The results substantiate the Environmental Kuznets hypothesis. The curve hypothesis posits that per capita income positively influences carbon emissions, whereas squared income exerts a negative effect. Energy consumption is recognised as the primary catalyst of emissions, highlighting the ongoing reliance of South Asian BRI economies on carbon-intensive energy infrastructure. Foreign direct investment and technological advancement reduce emissions over time, reinforcing the notion that technology transfer, innovation, and sustainable industrial methods can improve environmental outcomes. Export diversification exerts a negative, albeit statistically negligible, impact, indicating that diversity alone is inadequate for emission reduction unless it redirects output towards cleaner, higher-value sectors. The substantial, negative coefficient of the interaction term between per capita income and institutional quality indicates that robust institutions mitigate the emissions-increasing impact of economic growth. The report indicates that sustained growth in South Asian BRI nations requires not only economic expansion but also institutional strengthening, energy transition, and technological advancement.

1. INTRODUCTION

Carbon dioxide emissions continue to pose one of the most difficult environmental challenges for developing economies. Rapid industrialisation, urban expansion, and infrastructure investment have placed growing pressure on environmental systems, particularly where economic growth still depends on fossil-fuel-based energy. The urgency of the issue has sharpened since the Paris Agreement, which committed signatory states to limiting global temperature rise and accelerating climate mitigation (UNFCCC, 2015). For developing regions such as South Asia, the difficulty is compounded by the need to pursue economic growth, reduce poverty, expand infrastructure, secure energy supplies, and manage environmental costs simultaneously. The relationship between income growth and environmental degradation is commonly examined through the Environmental Kuznets Curve (EKC) hypothesis. The EKC posits that environmental degradation initially rises with income, but after a threshold level of development, further growth may reduce environmental pressure, producing an inverted U-shaped curve (Dinda, 2004; Grossman & Krueger, 1995). In the early stages of development, the scale effect tends to dominate: industrial expansion, rising production, and greater energy use generate higher emissions. At more advanced stages, structural change, technological improvement, better energy efficiency, and stronger environmental regulation may reduce the emission intensity of economic activity.

South Asian countries participating in the Belt and Road Initiative (BRI), Pakistan, India, Bangladesh, and Sri Lanka, offer a relevant context for examining this relationship. These economies have seen considerable change in infrastructure development, trade connectivity, foreign investment, and energy demand. While growth is necessary to support industrial activity and socioeconomic advancement, development in these countries has remained closely tied to carbon-intensive energy systems. The environmental consequences of economic growth in South Asian BRI countries, therefore, cannot be understood solely in terms of income. Energy use, export diversification, foreign direct investment (FDI), technological development, and institutional quality all shape the growth–emissions relationship.

Energy consumption is among the most direct channels through which economic activity affects emissions. Where demand is met primarily by coal, oil, and natural gas, increases in energy use tend to raise CO_2 output. Prior studies confirm that energy consumption is a major driver of environmental degradation and that the emission consequences of growth depend substantially on the energy mix (Nasir & Rehman, 2011; Soytas & Sari, 2009). This is particularly relevant for South Asia, where industrial activity, transport, urban development, and infrastructure investment continue to expand energy demand. Without structural change in energy systems, economic expansion is likely to remain environmentally costly.

The role of foreign direct investment is theoretically less settled. The pollution-haven hypothesis holds that FDI may raise emissions when multinational firms relocate pollution-intensive activity to countries with weaker environmental regulation. The pollution-halo hypothesis, by contrast, suggests that FDI can reduce emissions by transferring cleaner technologies, improving managerial practices, and raising production standards (Al-Mulali & Tang, 2013; Demena & Afesorgbor, 2020). Whether FDI improves or worsens environmental outcomes depends on the sectoral composition of investment, the host country's technological capacity, and the effectiveness of domestic institutions. Export diversification adds further complexity. Diversification may raise emissions if it expands energy-intensive manufacturing, but may reduce them if it shifts production toward higher-value, cleaner goods. Can and Saboori (2020) argue that the environmental consequences of diversification depend on the structure and technological content of exports. In South Asia, diversification alone is unlikely to improve environmental quality unless cleaner production processes, energy efficiency, and stronger regulation support it.

Technological development is widely recognised as a mechanism for reducing the environmental costs of growth. Innovation improves energy efficiency, lowers emission intensity, and supports cleaner production. Within the EKC framework, technological progress is one of the main channels through which economies can transition from an emission-increasing to an emission-reducing phase of development. The environmental returns to technology, however, depend on the direction of innovation and the capacity to adopt and diffuse it. In developing economies, limited financing, weak institutional capacity, and uneven technological absorption often restrict this potential.

Institutional quality shapes much of this. North (1990) defines institutions as the formal and informal rules that structure economic behaviour and influence long-run outcomes. In the environmental domain, strong institutions can improve regulatory enforcement, reduce corruption, support public accountability, encourage cleaner technologies, and direct investment toward sustainable activities. Weak institutions, by contrast, may allow growth to proceed through pollution-intensive channels because environmental compliance is limited and policy implementation is inconsistent. This study argues that institutional quality should be treated not only as a direct determinant of emissions, but also as a factor that moderates the relationship between economic growth and carbon output. When institutions are weak, income growth may increase emissions because regulatory enforcement is limited and expansion tends to rely on fossil-fuel-based activity. When institutions are stronger, the same increase in income may generate lower emissions because governments can better enforce environmental standards, monitor pollution, promote cleaner technologies, and channel investment toward less carbon-intensive sectors. Stronger institutional quality, on this view, reduces the environmental cost of growth.

Despite a substantial literature on the income–emissions relationship, several gaps remain. First, South Asian BRI participant countries have received limited attention as a regional group, despite their growing role in infrastructure-led development and climate negotiations. Second, much of the existing work treats institutional quality as a direct explanatory variable rather than examining whether it moderates the growth–emissions relationship. Third, export diversification remains underexplored in South Asian environmental research. Fourth, the combined influence of growth, energy consumption, FDI, technology, diversification, and institutional quality has not been examined within a unified long-run framework for this region. To address these gaps, this study analyses the long-run determinants of carbon emissions in Pakistan, India, Bangladesh, and Sri Lanka over 1984–2019. The EKC hypothesis is tested through per capita income and its square. The study further examines energy consumption, export diversification, FDI, and technological development. An interaction term between per capita income and institutional quality is introduced to test whether stronger institutions attenuate the growth-induced increase in emissions.

The study contributes to the literature in four respects. First, it extends the EKC analysis to South Asian BRI countries as a distinct regional group. Second, it examines institutional quality as a moderating variable rather than treating it solely as a direct control. Third, it incorporates energy consumption, export diversification, FDI, and technology in a unified framework. Fourth, it uses a panel Autoregressive Distributed Lag (ARDL) estimator, which is suited to long-run analysis and dynamic adjustment in heterogeneous panel settings (Pesaran et al., 1999).

The remainder of the paper proceeds as follows. Section 2 reviews the relevant literature and develops the research hypotheses. Section 3 describes the data, variables, model specification, and econometric approach. Section 4 presents and discusses the empirical findings. Section 5 concludes with the main findings, policy implications, limitations, and directions for future research.

1.1 Research Objectives

This study examines the long-run relationship between economic growth and carbon emissions in selected South Asian countries participating in the Belt and Road Initiative. Specifically, the study pursues the following objectives:

❖ First, to test the validity of the Environmental Kuznets Curve hypothesis by examining whether the relationship between per capita income and carbon emissions follows an inverted U-shaped pattern.

❖ Second, to assess the effects of energy consumption, export diversification, foreign direct investment, and technological development on carbon emissions in South Asian BRI participant countries.

❖ Third, to investigate whether institutional quality moderates the relationship between economic growth and carbon emissions.

❖ Fourth, to evaluate whether stronger institutional frameworks can reduce the environmental cost of economic growth in the context of South Asian BRI economies.Research Objectives

1.2 Research Contributions

This study contributes to the existing literature in several important ways.

❖ First, it extends the Environmental Kuznets Curve literature by examining the growth–emissions relationship in South Asian countries participating in the Belt and Road Initiative. This regional focus is important because these economies are experiencing rapid infrastructure development, rising energy demand, and increasing environmental pressure.

❖ Second, the study incorporates institutional quality as a moderating factor in the economic growth–carbon emissions nexus. Rather than treating institutions as a simple control variable, the analysis examines whether stronger institutions can reduce the environmental burden of economic expansion. This provides a more policy-relevant understanding of how governance quality shapes sustainable development outcomes.

❖ Third, the study includes energy consumption, export diversification, foreign direct investment, and technological development as key determinants of carbon emissions. This broader model helps reduce omitted-variable bias and provides a more comprehensive explanation of environmental degradation in the sampled countries.

❖ Fourth, the study employs a long-run ARDL framework to capture the dynamic nature of the variables and the long-run equilibrium relationships among economic growth, institutional quality, and carbon emissions. This approach is suitable for examining environmental-economic relationships that evolve gradually over time.

1.3 Conceptual Framework

Figure 1 presents the conceptual framework of the study. The framework is based on the Environmental Kuznets Curve hypothesis and institutional economics. Carbon emissions are treated as the dependent variable, while economic growth and squared income capture the nonlinear EKC relationship. Energy consumption, export diversification, foreign direct investment, and technological development are included as key determinants of carbon emissions. Institutional quality is introduced as a moderating variable, indicating that stronger institutions may weaken the positive effect of economic growth on carbon emissions.

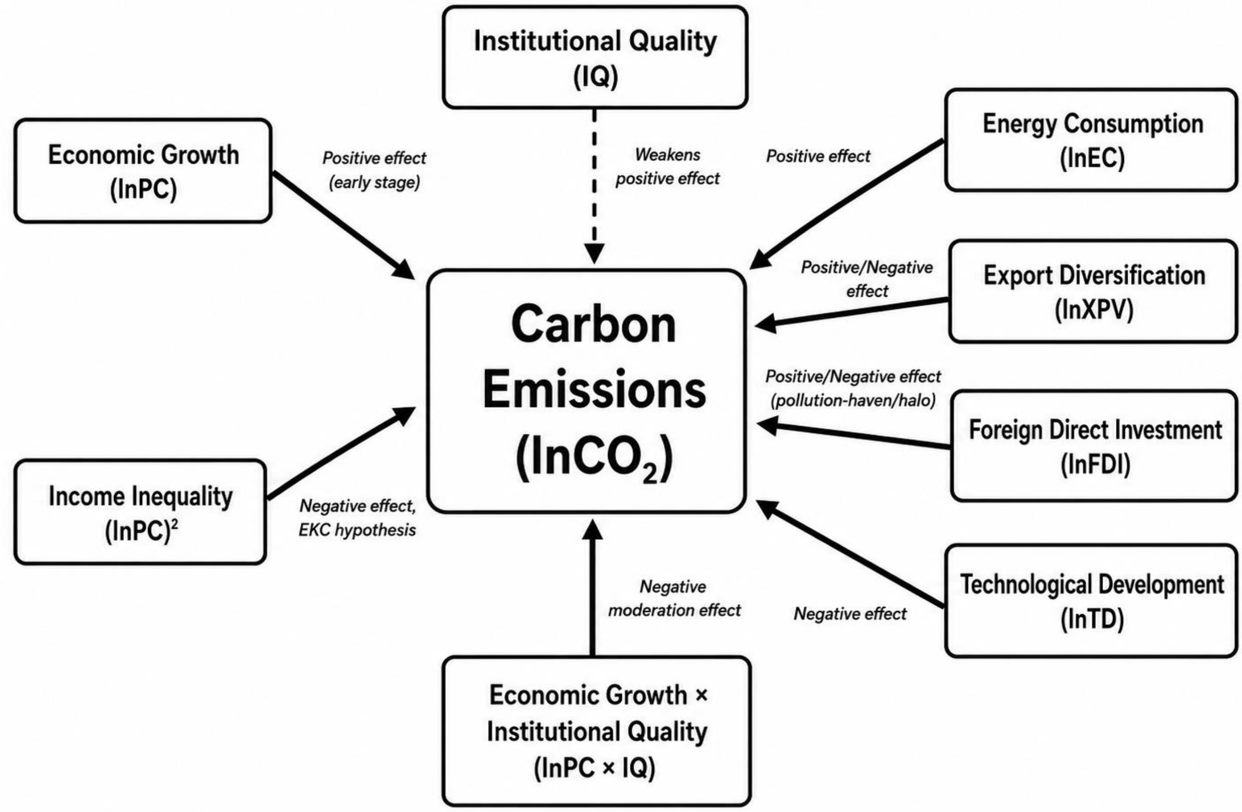

Figure 1. Conceptual framework showing the moderating role of institutional quality in the economic growth–carbon emissions nexus.

As shown in Figure 1, economic growth is expected to increase carbon emissions at the early stage of development, while the squared income term captures the emission-reducing stage of the EKC hypothesis. Energy consumption is expected to increase emissions, whereas technological development is expected to reduce them. The effects of export diversification and foreign direct investment may be positive or negative, depending on the sectoral structure of exports and the pollution-haven or pollution-halo nature of investment. The central argument of the framework is that institutional quality moderates the income–emissions relationship by reducing the environmental cost of economic growth.

2. Literature Review

2.1 Environmental Kuznets Curve Hypothesis

The EKC hypothesis, first formalised by Grossman and Krueger (1995) and extended by Dinda (2004), posits an inverted U-shaped relationship between per capita income and environmental degradation. In the early stages of development, the scale effect dominates industrial expansion, infrastructure investment, and rising production, driving up energy use and pollution. As income rises beyond a threshold, the composition effect and technique effect may take over: economies shift toward services, adopt cleaner technologies, improve energy efficiency, and tighten environmental regulation, eventually reducing emission intensity.

Empirical evidence on the EKC hypothesis is far from settled. Several studies confirm the inverted U-shaped pattern. Apergis and Payne (2009) found support for the EKC across a panel of Central American countries, and Stern (2004) identified similar patterns in cross-country data covering multiple decades. Ahmed et al. (2016) confirmed EKC-consistent results for Pakistan, attributing the turning point to improvements in energy efficiency and gradual industrial restructuring. By contrast, other studies find no such turning point. Lau et al. (2014) found a monotonically increasing income–emissions relationship in Malaysia, arguing that structural transformation had not yet reached a level where composition and technological effects could offset scale effects. Shahbaz et al. (2013) produced comparable findings for Indonesia, where continued dependence on coal-based energy prevented any reduction in emission intensity despite rising income. These divergent findings suggest that, if it exists, the EKC turning point is not determined solely by income. Energy structure, industrial composition, institutional capacity, and policy enforcement all shape whether higher income translates into lower emissions. For South Asia, this is particularly relevant. These economies are still in mid-transition, urbanising rapidly, expanding industrial capacity, and building infrastructure while remaining heavily dependent on fossil fuels. Applying the EKC framework to South Asian BRI participant countries, therefore, tests not just whether growth eventually reduces emissions, but under what structural and institutional conditions it might do so.

2.2 Institutional Quality and Environmental Outcomes

North (1990) defined institutions as the formal and informal rules that structure economic behaviour and shape long-run development outcomes. Applied to environmental policy, this framework implies that the effectiveness of emission controls depends not only on the existence of regulations but also on their credible enforcement. Bureaucratic capacity, corruption control, property-right security, and public accountability all determine whether environmental standards translate into actual changes in firm behaviour. Empirical research on the relationship between institutional quality and emissions has received growing attention. Lv and Xu (2019) found that governance quality significantly reduced CO_2 emissions across a panel of 129 countries, with the effect stronger in economies with more consistent regulatory enforcement. Fredriksson and Millimet (2002) showed that corruption weakened the stringency of environmental policy implementation in US states, suggesting that the formal existence of regulations is insufficient without institutional credibility. Zafar et al. (2021) found similar results for G20 economies, where stricter rule of law and government effectiveness were associated with lower per capita emissions even after controlling for income and energy use.

Beyond its direct effect, institutional quality may moderate the relationship between income growth and emissions. Khan et al. (2021) examined this interaction across a panel of developing economies and found that the EKC turning point occurred at a lower income level, where institutional quality was higher, suggesting that stronger governance accelerates the transition to cleaner growth. Conversely, Baloch et al. (2019) showed that in economies with weak institutions, income growth continued to raise emissions well past conventional turning-point estimates, because environmental compliance remained low and investment continued to flow toward pollution-intensive sectors. These findings support treating institutional quality not merely as a control variable but as a factor that shapes the income–emissions slope itself, an approach adopted in the present study.

2.3 Energy Consumption and Carbon Emissions

The link between energy consumption and CO_2 emissions is among the most consistently supported findings in environmental economics. Where energy demand is met primarily by fossil fuels, higher consumption directly translates into higher emissions. Soytas and Sari (2009) confirmed a long-run positive relationship between energy use and emissions across G7 economies, and Nasir and Rehman (2011) replicated this result for Pakistan, finding that energy consumption was the dominant driver of CO_2 output over the period 1972–2008. For South Asia more broadly, the energy–emissions relationship carries additional weight because industrialisation, urbanisation, and infrastructure expansion have all generated sustained growth in energy demand, much of it met by coal and petroleum. Shahbaz et al. (2017) examined energy consumption and emissions in India and found that the emission elasticity of energy was higher than that of income, implying that energy-sector transformation was a more urgent policy lever than income-driven compositional change. Pao and Tsai (2011) similarly found that energy consumption dominated the emissions trajectories of BRIC economies, with structural shifts in the energy mix having a larger effect than changes in output composition.

The energy–emissions relationship also complicates the prediction of the EKC. Even where income growth eventually supports better environmental regulation, emissions may not fall if the energy structure remains carbon-intensive. This makes energy consumption a necessary control variable in any model of carbon emissions, and its coefficient provides direct evidence on whether sampled economies have begun to decouple output growth from fossil-fuel dependence.

2.4 Export Diversification and Environmental Quality

The environmental consequences of export diversification depend largely on the composition and technological content of the export basket. Diversification toward higher-value, technology-intensive goods may reduce emissions intensity by shifting production away from resource extraction and heavy manufacturing. Diversification toward additional low-value manufactures or commodity processing, however, may raise energy demand and emissions without improving productive efficiency. Can and Saboori (2020) examined this relationship across a panel of developing countries and found that the direction of diversification mattered more than its extent: economies that diversified into cleaner, higher-complexity goods saw emission reductions, while those that diversified within carbon-intensive sectors did not. Haseeb et al. (2021) found a similar pattern in ASEAN economies: export diversification reduced emissions only in countries that simultaneously improved energy efficiency and regulatory stringency. Shahbaz et al. (2021) extended this to South Asia, finding that Bangladesh and Pakistan showed no significant emission reduction from diversification, largely because export expansion remained concentrated in textile and leather manufacturing sectors with high energy and water intensity.

These findings suggest that for South Asian BRI economies, the emission effect of export diversification is theoretically ambiguous and empirically contingent. Testing it within the present framework, alongside energy consumption and institutional quality, allows for a more complete picture of how trade structure interacts with the growth–emissions relationship.

2.5 Foreign Direct Investment and Carbon Emissions

Two competing hypotheses dominate the FDI–environment literature. The pollution-haven hypothesis holds that multinational firms relocate pollution-intensive production to countries with weaker environmental standards, raising host-country emissions (Copeland & Taylor, 2004). The pollution-halo hypothesis counters that FDI can reduce emissions by transferring cleaner technologies, raising production standards, and improving managerial practice in host firms (Demena & Afesorgbor, 2020).

Empirical evidence supports both sides, depending on the setting. Al-Mulali and Tang (2013) found that FDI increased emissions in a panel of Middle Eastern and North African economies with limited regulatory capacity. Pazienza (2019) reached the opposite conclusion for OECD countries, where FDI was associated with emission reductions, consistent with the halo hypothesis. For South Asia, Shahbaz et al. (2015) found that FDI increased emissions in Pakistan over the long run, attributing this to investment concentration in energy-intensive manufacturing and inadequate environmental enforcement. Ahmed et al. (2020), examining India, found the opposite — FDI inflows were associated with lower emission intensity, which they attributed to technology transfer in the services and pharmaceutical sectors.

The divergence across these studies implies that the environmental effect of FDI is not inherent to investment itself but shaped by the institutional context in which it occurs. In economies where regulatory enforcement is credible and domestic absorptive capacity is sufficient, FDI is more likely to generate the halo effect. Where institutions are weak, the haven effect may dominate. This makes FDI an important variable to include in a model that also incorporates institutional quality.

2.6 Technological Development and Emissions Mitigation

Technological innovation is widely regarded as central to decouple economic growth from emission growth. Improvements in energy efficiency reduce the fuel input required per unit of output; cleaner production processes reduce the emission intensity; and the diffusion of renewable energy technologies reduces the carbon content of the energy supply. Within the EKC framework, technological progress is one of the primary mechanisms through which the technique effect may eventually outweigh the scale effect.

Empirical support for this relationship is substantial, though not without qualification. Sadorsky (2012) found that technological development, measured through patent applications and R&D expenditures, reduced CO_2 emissions across a panel of G7 economies, with the effect operating primarily through improvements in energy efficiency. Acheampong et al. (2021) confirmed similar results for sub-Saharan Africa, but found the magnitude was smaller in countries with weak absorptive capacity, where technology adoption was constrained by limited financing and low skill levels. For South Asia, Shahbaz et al. (2022) found that innovation reduced emissions in India over the period 1971–2018, but found no statistically significant effect in Pakistan, Bangladesh, or Sri Lanka, suggesting that the institutional and financial conditions for technology diffusion were insufficiently developed.

These findings reinforce the argument that technological development reduces emissions under the right conditions. In economies with low institutional quality and limited technological absorption, innovation may not translate into emission reductions, even if the productive capacity for cleaner technologies exists. These points again highlight the importance of examining technological development alongside institutional quality rather than treating them as independent determinants.

2.7 Research Gap and Study Positioning

The literature reviewed above reveals four specific gaps that this study addresses. First, while the EKC hypothesis has been tested extensively in individual South Asian countries, it has rarely been examined for the region's BRI participant economies as a group, despite the relevance of BRI infrastructure investment for energy demand and emission trajectories. Second, institutional quality has been incorporated primarily as a direct determinant of emissions; fewer studies have examined whether it moderates the income–emissions relationship, particularly in South Asian contexts. Third, export diversification has received limited attention in South Asian environmental research, even as trade structure continues to change substantially under BRI-related integration. Fourth, no study known to the authors has jointly examined energy consumption, export diversification, FDI, technological development, and institutional quality, including its moderating role, within a single long-run framework for this country group.

This study addresses these gaps by testing the EKC hypothesis across Pakistan, India, Bangladesh, and Sri Lanka over 1984–2019, and by introducing an interaction between per capita income and institutional quality to examine whether stronger institutions reduce the emission cost of growth. The inclusion of energy consumption, export diversification, FDI, and technology within a panel ARDL framework provides a broader, more integrated analysis of long-run emission determinants than prior single-country or single-variable studies have.

2.8 Theoretical Framework and Hypotheses

This study is grounded in the Environmental Kuznets Curve framework, which proposes a nonlinear relationship between economic growth and environmental degradation. At lower levels of income, economic growth is expected to increase carbon emissions because production expansion, industrialisation, infrastructure development, and energy demand intensify environmental pressure. At higher levels of income, further growth may reduce emissions through structural transformation, technological upgrading, improved energy efficiency, and stronger environmental governance. The study further argues that institutional quality moderates the relationship between economic growth and carbon emissions. Strong institutions can reduce the environmental cost of growth by enforcing regulations, reducing corruption, improving monitoring capacity, and encouraging cleaner technologies. Weak institutions, in contrast, may allow economic expansion to occur through pollution-intensive channels. Therefore, the effect of income growth on emissions is expected to be weaker in countries with stronger institutional quality.

Based on this framework, the following hypotheses are proposed:

- ❖ H1: Economic growth has a nonlinear relationship with carbon emissions, such that per capita income increases CO_2 emissions while squared per capita income reduces CO_2 emissions.
- ❖ H2: Energy consumption has a positive effect on CO_2 emissions.
- ❖ H3: Export diversification significantly influences CO_2 emissions, although the direction of the effect depends on the sectoral and technological composition of exports.
- ❖ H4: Foreign direct investment affects CO_2 emissions through either pollution-haven or pollution-halo mechanisms.
- ❖ H5: Technological development reduces CO_2 emissions.
- ❖ H6: Institutional quality negatively moderates the relationship between economic growth and CO_2 emissions, such that stronger institutions weaken the positive effect of income growth on emissions.

3 Methodology

3.1 Research Design

This study employs a quantitative panel-data design to examine the long-run relationship among economic growth, institutional quality, and carbon emissions across selected South Asian countries participating in the Belt and Road Initiative. The empirical analysis is grounded in the Environmental Kuznets Curve framework, which assumes that the relationship between income and environmental degradation is nonlinear. In this framework, economic growth may initially increase carbon emissions through industrial expansion, higher energy demand, and greater production intensity. However, after a certain level of development, further income growth may reduce environmental pressure through structural transformation, improved energy efficiency, technological advancement, and stronger institutional capacity. The study follows a deductive research approach, in which the hypotheses are derived from established environmental economics theory and then tested using annual macroeconomic data. Since the analysis relies on secondary data and econometric modelling, the study does not employ a mixed-methods or qualitative research design. Instead, it uses panel econometric techniques to evaluate whether institutional quality moderates the relationship between per capita income and carbon emissions. This approach is suitable because the sampled countries share regional similarities but also differ in institutional capacity, energy structure, trade exposure, and economic development.

3.2 Data, Sample, and Variables

The analysis is based on annual panel data for four South Asian BRI participant countries: Pakistan, India, Bangladesh, and Sri Lanka. The study period covers 1984–2019, subject to data availability. These countries are selected because they are central to South Asia's economic and environmental transformation and have experienced rapid changes in energy consumption, trade integration, infrastructure development, and institutional reform. Their participation in BRI-related development also makes them relevant for examining the environmental implications of infrastructure-led growth. Carbon dioxide emissions are used as the dependent variable and expressed in logarithmic form. Per capita income and its squared term are included to test the Environmental Kuznets Curve hypothesis. Energy consumption is included because it is widely regarded as one of the most direct drivers of carbon emissions. Export diversification is included to assess whether changes in the export structure influence environmental outcomes. Foreign direct investment is used to test whether external capital inflows follow a pollution-haven or pollution-halo channel. Technological development is included to capture the role of innovation and cleaner production capacity.

Institutional quality is used as the main moderating variable because institutional effectiveness can shape the relationship between economic growth and environmental degradation.

To examine the moderating role of institutional quality, the study includes an interaction term between per capita income and institutional quality. This interaction term allows the analysis to determine whether stronger institutions reduce the carbon-emission effect of economic growth. A negative and statistically significant interaction coefficient would indicate that institutional quality weakens the positive association between income growth and emissions.

3.3 Econometric Model

To examine the long-run determinants of carbon emissions, the study estimates the following model:

$$lnCO2it = \alpha i + \beta 1lnPCit + \beta 2(lnPCit)2 + \beta 3lnECit + \beta 4lnXPVit + \beta 5lnFDIit + \beta 6lnTDit + \beta 7IQit + \beta 8(lnPCit \times I$$

The expected signs are as follows: $\beta_1 > 0$and $\beta_2 < 0$would support the EKC hypothesis; $\beta_3 > 0$is expected for energy consumption; $\beta_5$may be positive or negative depending on whether FDI follows the pollution-haven or pollution-halo channel; $\beta_6 < 0$is expected for technological development; and $\beta_8 < 0$would indicate that institutional quality reduces the environmental cost of economic growth. The expected signs of the coefficients are theoretically grounded. A positive coefficient of $\ln PC$and a negative coefficient of $(\ln PC)^2$would support the Environmental Kuznets Curve hypothesis. A positive coefficient of energy consumption is expected because higher energy use, particularly from fossil-fuel-based sources, tends to increase emissions. The coefficient of export diversification may be positive or negative depending on whether diversification occurs in carbon-intensive or cleaner sectors. The coefficient on FDI may also be positive or negative, depending on whether foreign investment supports pollution-intensive production or promotes cleaner technologies. Technological development is expected to reduce emissions. Finally, a negative coefficient of the interaction term would indicate that stronger institutions reduce the environmental cost of economic growth.

3.4 Panel ARDL Estimation Strategy

To estimate the long-run and short-run relationships among the variables, this study employs the panel Autoregressive Distributed Lag approach. The ARDL framework is suitable because it allows the model to capture dynamic adjustment processes and long-run equilibrium relationships. This is particularly important in environmental-economic analysis because changes in income, energy consumption, institutional quality, and technology may influence emissions gradually rather than immediately.

The general panel ARDL error-correction form can be written as:

$$\Delta Yit = \phi i(Yi,t - 1 - \theta i'Xi,t - 1) + j = 1\sum p - 1\lambda ij * \Delta Yi,t - j + j = 0\sum q - 1\delta ij * \Delta Xi,t - j + \mu i + \varepsilon it$$

where Y_{it}represents the dependent variable, $X_{it}$is the vector of explanatory variables, Δdenotes the first-difference operator, $\phi_i$is the error-correction coefficient, and $\theta_i$represents the vector of long-run coefficients. In this study, Y_{it}refers to carbon emissions, measured as $\ln CO_{2it}$, while X_{it}includes $\ln PC$, $(\ln PC)^2$, $\ln EC$, $\ln XPV$, $\ln FDI$, $\ln TD$, IQ, and $\ln PC \times IQ$. The coefficient $\phi_i$is expected to be negative and statistically significant, indicating that short-run deviations from the long-run equilibrium are corrected over time.

The Pooled Mean Group estimator is appropriate because it allows short-run coefficients, error variances, and adjustment speeds to differ across countries while constraining the long-run coefficients to be homogeneous. This assumption is suitable for the present study because South Asian BRI countries may differ in their short-run economic conditions, energy structures, and institutional responses. At the same time, their long-run development, common regional and structural characteristics may shape the emissions relationship.

3.5 Diagnostic and Robustness Tests

Before estimating the long-run model, several diagnostic tests are conducted to ensure the reliability of the empirical results. First, cross-sectional dependence is examined because South Asian economies may be affected by common regional shocks, trade linkages, energy-price movements, and policy spillovers. Ignoring cross-sectional dependence can lead to biased and inefficient estimates. Second, unit root tests are applied to examine the stationarity properties of the variables. Third, co-integration tests are used to confirm the existence of a stable long-run relationship among carbon emissions, income, energy consumption, institutional quality, and other explanatory variables. Fourth, lag length is selected using information criteria such as AIC and SIC. Finally, diagnostic tests for serial correlation, heteroskedasticity, and model stability are used to evaluate the adequacy of the estimated model.

4. Empirical Results and Discussion

This section presents and discusses the study's empirical findings. The analysis begins with the correlation matrix to examine the preliminary associations among the variables. This is followed by cross-sectional dependence testing to determine whether the sampled countries are affected by common shocks and regional spillovers. The stationarity properties of the variables are then examined through panel unit root testing, followed by co-integration analysis to confirm the existence of a stable long-run relationship among the variables. Finally, the long-run ARDL/PMG estimation results are reported and interpreted in relation to the Environmental Kuznets Curve hypothesis and the moderating role of institutional quality.

4.1 Correlation Analysis

Table 1. Correlation Analysis

Variables	GDP	CO_2	EN	TO	BRI	IQ	EF
GDP	1.000						
CO_2	0.274	1.000					
EN	0.575	0.850	1.000				
TO	0.671	0.003	0.340	1.000			
BRI	0.285	0.260	0.193	0.059	1.000		
IQ	0.318	0.533	0.472	0.290	0.094	1.000	
EF	0.621	0.435	0.486	0.403	0.201	0.728	1.000

Notes: GDP represents economic growth, CO_2 represents carbon emissions, EN represents energy consumption, TO represents trade openness, BRI represents Belt and Road Initiative participation, IQ represents institutional quality, and EF represents economic freedom.

Table 1 reports the correlation matrix among the major variables used in the study. The results provide preliminary evidence on the direction and strength of the associations among economic growth, carbon emissions, energy consumption, trade openness, institutional quality, economic freedom, and BRI participation. Although correlation analysis does not establish causality, it is useful for identifying initial patterns in the data before proceeding to dynamic panel estimation. The strongest correlation is observed between energy consumption and carbon emissions, with a coefficient of 0.850. This indicates that energy use is closely associated with environmental pressure in the sampled South Asian economies. The high positive correlation suggests that the carbon-emission profile of these countries is strongly linked to energy-intensive economic activity. This result is theoretically expected, as developing economies generally rely heavily on fossil fuels for industrial production, transport, infrastructure development, and electricity generation.GDP is positively correlated with energy consumption, trade openness, institutional quality, and economic freedom. This implies that economic expansion in the selected countries is associated with broader macroeconomic activity, higher energy demand, trade integration, and institutional development. However, the correlation between GDP and CO_2 emissions is moderate, at 0.274, suggesting that income growth alone does not fully explain emissions. This supports the need for a broader econometric model that includes energy consumption, export diversification, foreign direct investment, technological development, and institutional quality. The correlation between institutional quality and economic freedom is relatively high, at 0.728, but it remains below the conventional multicollinearity threshold. This suggests that while institutional quality and economic freedom are related, they are not perfectly collinear. Overall, the correlation matrix provides initial support for including the selected variables in the empirical model. However, since correlation analysis cannot account for dynamic relationships, endogeneity, non-stationarity, or long-run equilibrium behaviour, the study proceeds with panel diagnostic tests and ARDL/PMG estimation.

4.2 Cross-Sectional Dependence Test

Before conducting panel unit root and co-integration tests, it is necessary to examine whether cross-sectional dependence exists among the sampled countries. Cross-sectional dependence may arise when countries are exposed to common regional shocks, international energy price movements, trade linkages, financial spillovers, or shared infrastructure developments. Since Pakistan, India, Bangladesh, and Sri Lanka are geographically and economically connected, ignoring cross-sectional dependence may lead to biased test statistics and unreliable inference.

Table 2. Cross-Sectional Dependence Test Results

Model Specification	Breusch–Pagan LM	Pesaran scaled LM	Pesaran CD
Model 1: $lnCO_2$ = f(lnPC, lnEC, lnXPV, lnFDI, lnTD)	87.084	23.407	-4.438
Model 2: $lnCO_2$ = f(lnPC, lnEC, lnXPV, lnFDI, lnTD, IQ)	62.535	16.320	-4.431
Model 3: $lnCO_2$ = f(lnPC, lnEC, lnXPV, lnFDI, lnTD, lnPC × IQ)	70.646	18.661	-4.365

The cross-sectional dependence results reported in Table 2 indicate that the null hypothesis of cross-sectional independence is rejected across all model specifications. The Breusch–Pagan LM, Pesaran-scaled LM, and Pesaran CD statistics suggest that the sampled countries are not independent of one another. This result is theoretically plausible because South Asian economies are exposed to common regional shocks, energy-market fluctuations, trade linkages, and infrastructure-related policy spillovers. The presence of cross-sectional dependence justifies the use of econometric techniques that account for interdependence among panel units. It also supports the argument that environmental and macroeconomic outcomes in one country may be connected to broader regional dynamics rather than being purely domestic. To provide a clearer visual comparison of the cross-sectional dependence diagnostics, Figure 2 presents the Breusch–Pagan LM, Pesaran scaled LM, and Pesaran CD statistics across the three model specifications. The graphical results are consistent with Table 2 and confirm the presence of cross-sectional dependence among the sampled countries

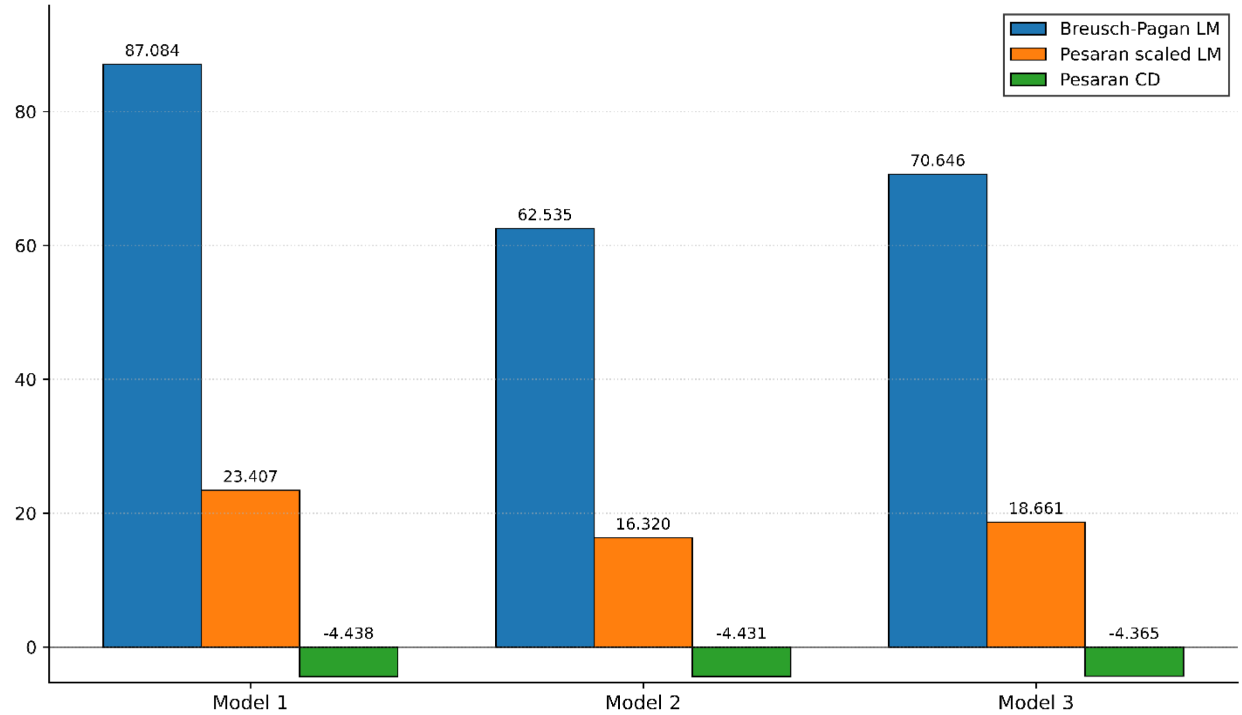

Figure 2. Graphical presentation of cross-sectional dependence test results based on Breusch–Pagan LM, Pesaran scaled LM, and Pesaran CD statistics across the three model specifications.

The results indicate that cross-sectional dependence is present across all model specifications. This finding is expected because South Asian BRI economies are exposed to common regional shocks, energy-market fluctuations, trade linkages, and infrastructure-related spillovers. Therefore, the subsequent econometric analysis accounts for cross-sectional interdependence through appropriate panel testing and estimation procedures.

Following evidence of cross-sectional dependence, this study employs second-generation panel unit root tests to assess the stationarity properties of the variables. This approach is necessary because conventional first-generation tests may yield biased results when common shocks or regional spillovers influence cross-sectional units. Accordingly, the cross-sectionally augmented panel unit root test developed by Pesaran (2007) is adopted, as it accounts for unobserved common factors and cross-sectional interdependence. The results reveal that the variables are integrated at level, $I(0)$, or at first difference, $I(1)$, with none integrated of order two. This confirms the appropriateness of the panel ARDL framework, which accommodates mixed integration orders provided no variable is $I(2)$ (Pesaran et al., 1999; Pesaran, 2007). After establishing the stationarity properties, panel co-integration analysis is conducted to examine the existence of a stable long-run relationship among carbon emissions, per capita income, energy consumption, export diversification, foreign direct investment (FDI), technological development, and institutional quality. The Westerlund (2007) co-integration test is particularly suitable due to its error-correction-based framework and its ability to account for heterogeneity across panel units. The rejection of the null hypothesis of no co-integration indicates the presence of a long-run equilibrium relationship among the variables, thereby justifying the estimation of both long-run and short-run dynamics using the panel ARDL approach.

Given the existence of co-integration, the panel ARDL model is estimated using the Pooled Mean Group (PMG) estimator. This estimator allows short-run coefficients, error variances, and adjustment speeds to vary across countries while imposing homogeneity on long-run coefficients. This assumption is reasonable in this context, as Pakistan, India, Bangladesh, and Sri Lanka may differ in short-run policy responses and institutional settings but share similar long-run development and environmental challenges as South Asian Belt and Road Initiative (BRI) economies (Pesaran et al., 1999). The long-run results support the Environmental Kuznets Curve (EKC) hypothesis. Specifically, the positive coefficient of per capita income and the negative coefficient of its squared term indicate an inverted U-shaped relationship between economic growth and carbon emissions. This suggests that emissions initially rise with income growth due to industrialization, infrastructure expansion, and increased energy demand, but decline after a certain income threshold as economies transition toward cleaner technologies, improved energy efficiency, and stricter environmental regulations (Dinda, 2004; Grossman & Krueger, 1995).

Energy consumption emerges as a key driver of carbon emissions in both the short- and long-run. The positive and statistically significant coefficient reflects the continued reliance of South Asian economies on carbon-intensive energy sources. This finding aligns with prior literature emphasizing the central role of energy consumption in environmental degradation in developing countries (Nasir & Rehman, 2011; Shahbaz et al., 2018). It also highlights the importance of energy sector reforms, including expanding renewable energy, improving energy efficiency, and gradually transitioning away from fossil fuels. Institutional quality plays a significant moderating role in the relationship between economic growth and carbon emissions. The negative, statistically significant interaction term between per capita income and institutional quality indicates that stronger institutions mitigate the growth-induced increase in emissions. This suggests that better governance enhances regulatory enforcement, reduces corruption, and supports the adoption of cleaner technologies.

In contrast, weak institutional frameworks may allow economic expansion to proceed through environmentally harmful channels. This finding is consistent with the institutional economics perspective, which emphasizes the role of governance in shaping development and environmental outcomes (North, 1990; Lau et al., 2014). Foreign direct investment and technological development also contribute to the dynamics of emissions. The negative coefficient of FDI supports the pollution-halo hypothesis, indicating that foreign investment can reduce emissions through technology transfer, improved management practices, and higher production standards. However, these benefits depend on institutional quality and the sectoral composition of investment. Similarly, the negative effect of technological development underscores the importance of innovation and technological advancement in reducing emissions through cleaner production processes and improved energy efficiency (Demena & Afesorgbor, 2020; Zhu et al., 2016). Export diversification, although negatively signed, is not statistically significant, suggesting a limited direct impact on carbon emissions in the long run. This implies that diversification alone is insufficient to improve environmental quality; its effectiveness depends on the nature of diversification. Shifting toward cleaner, high-value, and technology-intensive sectors is crucial, alongside the integration of environmental standards and sustainable production practices. Overall, the findings confirm a stable long-run relationship among carbon emissions and their key determinants. Energy consumption remains the dominant source of environmental pressure, while institutional quality and technological development play critical roles in reducing the carbon intensity of growth. The significant interaction effect further highlights that institutions actively shape whether economic growth leads to environmental degradation or sustainability.

4.3 Panel Unit Root and Co-integration Tests

Given evidence of cross-sectional dependence, this study employs second-generation panel unit root tests to assess the stationarity of the variables. This step is necessary because conventional first-generation unit root tests may yield biased results when common shocks or regional spillovers affect cross-sectional units. The cross-sectionally augmented panel unit root test developed by Pesaran (2007) is therefore appropriate because it accounts for unobserved common factors and cross-sectional interdependence.

The panel ARDL framework can accommodate variables integrated at level, I(0), and first difference, I(1), provided that none of the variables is integrated of order two, I(2). Therefore, the purpose of the unit root test is to ensure that the variables meet the integration requirements for ARDL estimation. The results indicate that the variables are integrated either at the level or at first difference, while none is integrated of order two. This confirms the suitability of the panel ARDL approach for estimating the long-run and short-run relationships among the variables

Table 3. Co-integration Test Results

Null Hypothesis	Trace Statistic	Critical Value (5%)	Max-Eigen Statistic	Critical Value (5%)
r = 0	174.52***	125.62	67.94***	46.23
r ≤ 1	106.58***	95.75	40.82**	40.08
r ≤ 2	65.77	69.82	25.45	33.88
r ≤ 3	40.32	47.86	19.11	27.58
r ≤ 4	21.21	29.80	12.37	21.13
r ≤ 5	8.84	15.50	8.73	14.26
r ≤ 6	0.12	3.84	0.12	3.84

Notes: ** and *** indicate significance at the 5% and 1% levels, respectively. The null hypothesis assumes no co-integrating relationship up to the stated rank.

Table 4 presents the co-integration test results based on the trace and maximum eigenvalue statistics. The results provide strong evidence of a long-run equilibrium relationship among carbon emissions, per capita income, energy consumption, export diversification, foreign direct investment, technological development, and institutional quality. For the null hypothesis of no co-integration (r=0), both the trace statistic (174.52) and the maximum eigenvalue statistic (67.94) exceed their respective 5% critical values of 125.62 and 46.23. Therefore, the null hypothesis of no co-integration is rejected at the 1% significance level. Similarly, for the null hypothesis r≤1, the trace statistic (106.58) exceeds the 5% critical value (95.75), and the maximum eigenvalue statistic (40.82) slightly exceeds its 5% critical value (40.08). This indicates the existence of at least two co-integrating relationships among the variables. However, for r≤2 and the subsequent ranks, both the trace and maximum eigenvalue statistics are lower than their respective critical values. Hence, the null hypotheses cannot be rejected beyond the second co-integrating vector.

These findings confirm that the variables included in the model are linked through a stable long-run relationship. In other words, carbon emissions and their key determinants do not move independently over time; rather, they share common long-run dynamics. This result is important because it validates the use of long-run estimation techniques and supports the application of the ARDL/PMG framework for examining both long-run equilibrium effects and short-run adjustment behaviour.

From an economic perspective, the presence of co-integration suggests that changes in economic growth, energy consumption, foreign direct investment, technological development, export diversification, and institutional quality are systematically associated with the long-run path of carbon emissions in South Asian BRI participant countries. Therefore, the subsequent ARDL/PMG estimates can be interpreted as meaningful long-run relationships rather than spurious correlations.

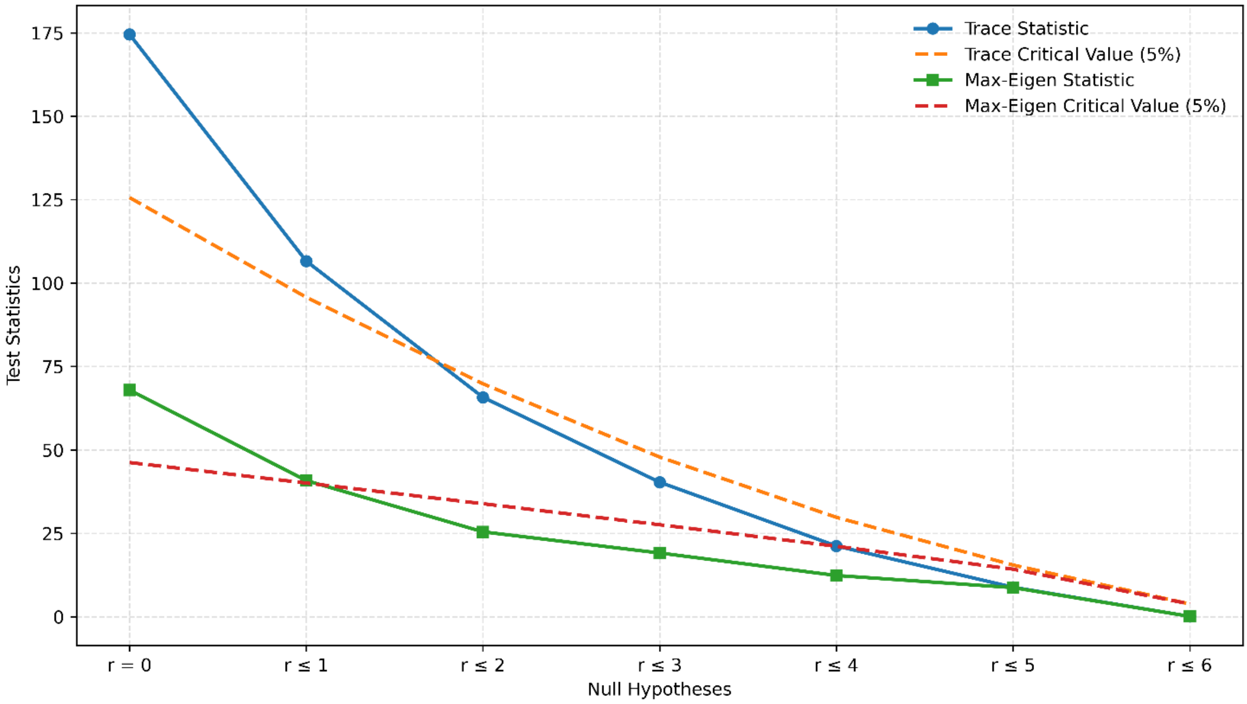

Figure 3. Johansen co-integration test results based on the trace and maximum eigenvalue statistics at the 5% significance level.

Table 3 and Figure 3 report the Johansen co-integration test results using the trace and maximum eigenvalue statistics. As shown in Figure X, both test statistics exceed their respective 5% critical values for $r = 0$and $r \leq 1$, indicating the existence of long-run co-integrating relationships among the variables. For higher co-integration ranks, the null hypothesis cannot be rejected, confirming a stable long-run equilibrium relationship.

4 Long-Run ARDL/PMG Estimation Results

Given the existence of co-integration, the long-run relationship among the variables is estimated using the panel ARDL model with the Pooled Mean Group estimator. The PMG estimator is appropriate because it allows short-run coefficients, error variances, and adjustment speeds to differ across countries while imposing homogeneity on long-run coefficients. This is suitable for the present study because Pakistan, India, Bangladesh, and Sri Lanka may differ in short-run policy responses, institutional conditions, and energy structures, while sharing similar long-run development and environmental challenges as South Asian BRI participant countries.

Table 5. Long-Run ARDL/PMG Estimation Results for the Determinants of CO_2 Emissions

Regressors	Coefficient	t-Statistic	Probability
Constant	-38.87*	-2.31	< 0.10
lnPC	10.58*	2.15	< 0.10
$(\ln PC)^2$	-0.76*	-2.12	< 0.10
lnEC	1.59***	7.22	< 0.01
lnXPV	-0.11	-0.29	> 0.10
lnFDI	-0.09**	-3.45	< 0.05
lnTD	-0.12**	-2.79	< 0.05
lnPC × IQ	-0.045**	-2.48	< 0.05

Notes: The dependent variable is $\ln CO_2$. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. lnPC represents per capita income, EC represents energy consumption, XPV represents export diversification, FDI represents foreign direct investment, TD represents technological development, and IQ denotes institutional quality.

The long-run ARDL/PMG results reported in Table 5 provide support for the Environmental Kuznets Curve hypothesis. The coefficient of per capita income is positive and statistically significant, while the coefficient of squared per capita income is negative and statistically significant. This combination of signs confirms an inverted U-shaped relationship between economic growth and carbon emissions. In the early stage of development, economic growth increases emissions through industrialisation, infrastructure expansion, higher production, and greater energy demand. However, once a certain level of development is reached, further growth may reduce emissions through structural transformation, improved energy efficiency, technological upgrading, and stronger environmental regulation.

Energy consumption is the strongest determinant of carbon emissions in the model. The coefficient of lnEC is positive and statistically significant at the 1% level. Specifically, a 1% increase in energy consumption is associated with an approximate 1.59% increase in carbon emissions in the long run. This elasticity is greater than unity, suggesting that emissions in the sampled South Asian BRI countries are highly responsive to changes in energy use. The finding highlights the continued dependence of these economies on carbon-intensive energy systems and indicates that energy-sector reform is central to any effective emissions-reduction strategy.

Export diversification has a negative but statistically insignificant coefficient. This suggests that export diversification does not exert a meaningful long-run effect on carbon emissions in the sampled countries. The insignificant result may reflect the mixed environmental consequences of diversification. If diversification expands energy-intensive manufacturing, emissions may increase. However, if diversification shifts production toward higher-value and technology-intensive sectors, emissions may decline. Therefore, export diversification alone is insufficient to reduce environmental degradation unless cleaner production methods, technological upgrading, and environmental standards accompany it. Foreign direct investment has a negative and statistically significant effect on carbon emissions. This finding supports the pollution-halo hypothesis, which suggests that FDI may improve environmental quality through technology transfer, better production practices, improved managerial capacity, and exposure to international environmental standards. However, the relatively small magnitude of the coefficient indicates that the environmental benefits of FDI remain modest. Therefore, foreign investment should be directed toward cleaner industries, renewable energy, sustainable infrastructure, and technology-intensive sectors to strengthen its environmental contribution. Technological development also has a negative and statistically significant coefficient. This result confirms that technological progress contributes to long-term reductions in emissions. A 1% improvement in technological development is associated with an approximate 0.12% reduction in carbon emissions. Although the magnitude is moderate, the result supports the view that innovation, energy-efficient technologies, cleaner production processes, and digital transformation can help reduce the carbon intensity of economic activity. For South Asian BRI economies, technological development is therefore an important pathway for achieving sustainable growth.

Most importantly, the interaction term between per capita income and institutional quality is negative and statistically significant. This confirms the moderating role of institutional quality in the economic growth–carbon emissions nexus. In practical terms, stronger institutional quality weakens the emission-increasing effect of economic growth. Countries with more effective governance, stronger regulatory enforcement, lower corruption, and better public accountability are better able to ensure that economic expansion does not lead to excessive environmental degradation. This finding is central to the study's contribution. It shows that economic growth alone does not determine environmental outcomes. Rather, the environmental consequences of growth depend on the institutional conditions under which development takes place. Strong institutions can guide investment toward cleaner sectors, enforce environmental standards, promote technological upgrading, and reduce the likelihood that pollution-intensive activities will drive growth. Therefore, institutional quality functions not only as a governance variable but also as a mechanism through which economic growth can become environmentally sustainable.

Overall, the empirical findings confirm a stable long-run relationship among carbon emissions and their key determinants. Energy consumption remains the dominant source of environmental pressure, while foreign direct investment, technological development, and institutional quality contribute to emissions reduction. The significant negative interaction term further demonstrates that institutional quality actively shapes the growth–emissions relationship. These findings suggest that sustainable development in South Asian BRI countries requires not only economic growth but also institutional strengthening, energy transition, and technological upgrading.

5. Conclusion

This study examined the long-run determinants of carbon emissions in selected South Asian countries participating in the Belt and Road Initiative, with particular emphasis on the moderating role of institutional quality in the economic growth–carbon emissions relationship. Using annual panel data for Pakistan, India, Bangladesh, and Sri Lanka over the period 1984–2019, the study employed a panel ARDL framework to test the Environmental Kuznets Curve hypothesis and to assess the effects of energy consumption, export diversification, foreign direct investment, technological development, and institutional quality on carbon emissions. The empirical findings provide support for the Environmental Kuznets Curve hypothesis. The positive coefficient for per capita income and the negative coefficient for its squared term indicate an inverted U-shaped relationship between economic growth and carbon emissions. This result suggests that, at earlier stages of development, income growth increases emissions through industrial expansion, rising energy use, and greater production activity. However, beyond a certain level of development, further economic growth may lower emissions through structural transformation, technological progress, improved efficiency, and stronger environmental governance.

Energy consumption is found to be the most influential driver of carbon emissions in the sampled countries. The long-run elasticity of energy consumption is positive, statistically significant, and greater than unity, indicating that emissions respond strongly to changes in energy demand. This finding highlights the continued dependence of South Asian BRI economies on carbon-intensive energy systems. It also suggests that emissions reductions cannot be achieved solely through income growth. Without substantial changes in the energy structure, economic expansion is likely to remain environmentally costly. Foreign direct investment is found to reduce carbon emissions, providing evidence in favour of the pollution-halo hypothesis. This indicates that foreign investment may improve environmental performance by transferring cleaner technologies, enhancing production efficiency, and introducing better managerial and environmental practices. Nevertheless, the relatively small magnitude of the coefficient suggests that the environmental benefits of FDI are not automatic. Policy frameworks must therefore guide foreign investment toward clean energy, low-carbon industries, and technology-intensive sectors.

Technological development also has a negative and statistically significant effect on carbon emissions. This confirms that innovation and technological upgrading are important pathways for reducing environmental degradation. However, the moderate size of the coefficient suggests that technology alone cannot fully offset the environmental pressure created by energy-intensive growth. For technological development to produce stronger environmental benefits, it must be supported by institutional reforms, investment incentives, research and development policies, and wider

diffusion of clean technologies across industries.
Export diversification does not show a statistically significant long-run effect on carbon emissions. This finding suggests that diversification by itself does not guarantee environmental improvement. The environmental consequences of diversification depend on the type of products exported, the energy intensity of production, the technological sophistication of industries, and the environmental standards imposed by international markets. Therefore, export policies should not only focus on increasing the number of export products but also encourage a shift toward cleaner, higher-value, and less resource-intensive sectors. The most important contribution of this study lies in its focus on institutional quality. The negative, statistically significant interaction coefficient between per capita income and institutional quality confirms that institutions moderate the relationship between economic growth and emissions. Stronger institutions reduce the environmental cost of economic growth by improving regulatory enforcement, reducing corruption, supporting environmental accountability, and facilitating the adoption of cleaner technologies. This finding indicates that economic growth becomes more environmentally sustainable when supported by effective governance structures.
Overall, the results suggest that South Asian BRI countries face a dual challenge: sustaining economic growth while reducing the environmental pressure associated with energy-intensive development. The findings show that growth, technology, FDI, and institutional quality can contribute to environmental improvement, but only when supported by coherent policy frameworks. In particular, the strong effect of energy consumption indicates that energy transition must remain the central pillar of climate and environmental policy in the region.

5.1 Policy Implications

The findings offer several important policy implications. First, energy-sector reform should be treated as the most urgent policy priority. Since energy consumption has the strongest positive effect on emissions, South Asian BRI countries should accelerate the transition toward renewable energy, improve energy efficiency, and reduce dependence on fossil fuels. Public investment, private-sector incentives, and regional cooperation can play an important role in expanding solar, wind, hydro, and other low-carbon energy sources.
Second, institutional strengthening is essential for sustainable development. The significant moderating role of institutional quality indicates that better governance can reduce the environmental cost of economic growth. Governments should strengthen environmental regulatory agencies, improve pollution monitoring systems, reduce corruption in environmental enforcement, and enhance judicial capacity for environmental protection. Institutional reforms should not be treated as separate from environmental policy; rather, they should be viewed as a core condition for successful emissions reduction. Third, foreign direct investment should be guided toward environmentally responsible sectors. Although FDI is found to reduce emissions, its benefits can be strengthened through green investment standards, environmental screening mechanisms, and incentives for the transfer of clean technology. Governments should prioritize FDI in renewable energy, sustainable infrastructure, high-technology manufacturing, and low-carbon services.
Fourth, technological development should be promoted through research and development support, industrial upgrading, and the diffusion of clean technologies. Policies that encourage energy-efficient machinery, digital monitoring systems, cleaner production methods, and green innovation can help reduce the carbon intensity of economic activity. Collaboration among universities, industry, and public institutions can further enhance the effectiveness of technology policy. Fifth, export diversification should be aligned with environmental objectives. Since export diversification alone does not significantly reduce emissions, governments should promote diversification into cleaner, higher-value sectors. Export incentives should be linked with environmental performance, energy efficiency, and compliance with international

sustainability standards. This would allow export expansion to support both economic competitiveness and environmental improvement.

5.2 Limitations and Future Research

This study has several limitations that provide opportunities for future research. First, the analysis is limited to four South Asian BRI participant countries. Although these countries are important for regional analysis, future research could include a broader set of BRI economies from Central Asia, Southeast Asia, the Middle East, and Africa to examine whether the findings remain valid across different regional and institutional contexts. Second, the study uses aggregate carbon emissions as the main environmental indicator. Future studies could examine other environmental outcomes, such as ecological footprint, methane emissions, particulate matter, sulfur dioxide, or sector-specific emissions. This would provide a more detailed understanding of environmental degradation. Third, institutional quality is measured as a broad governance indicator. Future research could disaggregate institutional quality into regulatory quality, government effectiveness, rule of law, corruption control, political stability, and voice and accountability. This would help identify which institutional dimensions are most important for reducing the environmental cost of growth.

Fourth, the BRI variable can be developed further. If BRI is measured only as a pre-2013 and post-2013 dummy, it may not fully capture the intensity and diversity of BRI-related investments. Future studies could use country-level BRI investment, infrastructure project data, energy project composition, or transport connectivity indicators to more effectively identify the environmental consequences of BRI participation. Fifth, future research could apply spatial econometric models or common correlated effects estimators to better account for regional spillovers and cross-sectional dependence. Since the sampled countries are economically and geographically connected, emissions and policy outcomes in one country may influence neighbouring countries.

5.3 Concluding Remarks

The study concludes that economic growth and environmental sustainability need not be mutually exclusive, but their compatibility depends on the quality of institutions, the structure of energy systems, and the direction of technological change. The evidence supports the view that institutional quality plays a central role in transforming economic growth into a more sustainable process. Strong institutions can ensure that growth is accompanied by cleaner technologies, stricter environmental enforcement, and more responsible investment patterns. For South Asian BRI countries, the policy challenge is not simply to grow faster, but to grow differently. Infrastructure development, trade expansion, and foreign investment must be embedded within a framework of environmental accountability and institutional effectiveness. If economic growth continues to rely heavily on fossil fuels and weak environmental enforcement persists, carbon emissions are likely to remain high. However, if growth is supported by renewable energy, technological upgrading, cleaner investment, and stronger institutions, the region can move toward a more sustainable development path.

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