Carbon Emissions, Water Scarcity and Geopolitics in South Asia: Evidence from Cross-Sectionally Dependent Panel

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ABSTRACT: This study investigates the role of environmental sustainability in shaping geopolitics in South Asia. Environmental Sustainability is proxied by carbon emissions and water scarcity, while control of corruption serves as a proxy for geopolitical governance. The analysis employs a balanced panel of selected South Asian countries over the period from 1996 to 2024. After confirming cross-sectional dependence, slope heterogeneity, mixed orders of integration, and long-run cointegration, the study employed the CS-ARDL model to estimate both long and short-run relationships. Robustness of the findings is examined through the application of PCSE. Findings revealed that carbon emission, GDP per capita, and renewable energy consumption are negatively associated with control of corruption, while water scarcity improves governance by encouraging institutional reforms and strengthening accountability mechanisms. In the short run, all the variables are insignificant except GDP per capita. The error correction coefficient is negative and statistically significant, showing that 29% of short-run deviations from the long-run equilibrium are corrected within each period. These findings contribute to the literature on the environment-geopolitics nexus by reversing the conventional causal perspective.

KEYWORDS: Environmental Sustainability, Control of Corruption, Geopolitics, Carbon Emissions, Water Scarcity, South Asia

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Introduction

In the current era, the geopolitical outcomes are influenced by determinants that extend beyond conventional sources of power, for example, military capabilities, economic strength, and diplomatic influence (Blackwill & Harris, 2016). Among the emerging determinants, environmental sustainability (ES) has gained particular importance. It affects the availability of critical resources, the resilience of economies, and the capacity of states to respond to shocks (Kim et al., 2022). Moreover, it influences geopolitical dynamics through interconnected channels, i.e., agricultural productivity, livelihoods, energy availability, and the distribution of natural resources, thereby generating socioeconomic pressures that may extend into the political sphere (Mehta, 2024). These implications become more important where resources are unevenly distributed or shared across national boundaries. However, environmental pressures do not translate automatically into adverse geopolitical outcomes. Their implications are conditioned by the effectiveness of governance mechanisms in managing resource pressures and competing interests (Mach et al., 2019). Accordingly, ES can be viewed as an important structural determinant of geopolitical outcomes, providing a basis for examining how environmental pressures and resource conditions influence the broader geopolitical position of states.

Carbon emissions (CE) reflect the carbon intensity of economic production and energy consumption that cause greenhouse-gas emissions and contribute to climate change. Persistent reliance on carbon-intensive production and fossil-fuel-based energy systems leads to dependence on conventional energy sources that increases exposure to energy-price volatility and constrains the capacity of economies to adapt to environmental shocks (Thombs, 2022). Moreover, these pressures extend beyond environmental and economic domains by creating additional challenges for policy coordination, resource management, and socioeconomic stability. Therefore, climate-related shocks influence political and geopolitical outcomes through economic, social, and institutional channels (Hoffart et al., 2024). Similarly, water scarcity (WS) is a more spatially concentrated dimension of environmental pressure, as its availability is linked to specific watersheds, river systems, and transboundary basins (Lodge et al., 2024). Given the central role of water in economic and human life, its persistent scarcity generates socioeconomic pressures and increases challenges for allocation of resources and governance. These challenges become more prominent in transboundary river basins. In such cases, the differences in water availability, allocation priorities, and upstream–downstream interests shape interdependence among states (Gold et al., 2023). If competition over shared water resources leads to interstate conflicts, the mutual dependence also creates incentives for cooperation in resource management. Evidence from the Indus Basin highlights how integrated water-resource management and environmental cooperation can contribute to improved regional outcomes (Bilalova et al., 2023). Thus, both dimensions provide complementary pathways through which environmental conditions can ultimately shape geopolitical outcomes.

South Asia, on the one hand, experienced rapid population growth and economic transformation, while on the other, the economies are dependent on agriculture and other climate-sensitive resources (Shahzad et al., 2024), which increase the region's vulnerability to environmental pressures. Moreover, the network of transboundary river systems further increases interdependencies. Resource-use decisions in one country affect the others. Additionally, changes in climate conditions threaten water and agricultural systems, hence increasing the importance of effective resource governance and cross-border policy coordination (Cassidy-Neumiller et al., 2024). These characteristics make South Asia an important case for examining how CE and WS are associated with geopolitical outcomes. Against this background, the present study employs the control of corruption (CC) indicator as a measure of geopolitical outcomes. CC reflects the extent to which public authority is exercised free from corruption and therefore provides a channel through which environmental pressures may be associated with governance and geopolitical outcomes (Shadabi & Adkisson, 2021).

Although the literature discusses climate-related conflicts (Koubi, 2019), resource governance (Rahman et al., 2017), water-related tensions (Bernauer & Böhmelt, 2020), and the relationship between CE and economic development (Li et al., 2023), limited empirical attention has been given to the joint role of CE and WS as distinct environmental pressures in shaping geopolitics in South Asia. This omission is important because the two indicators capture different dimensions of environmental stress. For example, CE is linked to long-term climate risk arising from energy use, while WS is the location-specific pressure on a resource necessary for production and human well-being. Therefore, analysing them within a common framework enhances understanding of how environmental pressures interact with geopolitical outcomes.

Against this background, the study asks: To what extent do environmental pressures influence geopolitical outcomes in South Asia? To answer this question, this study contributes to the literature in the following ways: first, unlike previous literature that treated geopolitics solely in terms of military or diplomatic power, this study links environmental pressure to geopolitical outcomes through a governance perspective. Second, this study considers both CE and WS, which are distinct environmental channels that may have implications for governance. Third, it takes South Asia as a case study, which is most relevant because of its transboundary resources, environmental vulnerability, and governance heterogeneity. Fourth, we incorporated GDP per capita and renewable energy consumption as control variables to capture the role of development and energy transition while analysing the association between environment and governance. Finally, to capture the temporal nature of the relationship, we distinguish between long- and short-run effects.

The paper is organized as follows: the next section reviews the empirical literature. Section 3 presents the data, variables, and methodology, followed by the empirical findings and robustness analysis in Section 4. The final section concludes with policy implications and limitations.

Literature Review

Traditionally, the growing geopolitical conflicts and environmental degradation have been examined as separate domains. Geopolitical research focuses on military conflicts, political instability, and territorial disputes, while environmental sustainability research focuses on climate change mitigation, conservation of resources, and protection of ecosystems. However, these processes are interconnected; for example, if geopolitical conditions influence environmental outcomes through several channels, environmental pressure also has serious consequences for resource governance and institutional resilience. Despite this recognition, past studies are one directional where they emphasize the role of geopolitical conditions in environmental sustainability and rarely investigating the vice versa, where environmental degradation might shape geopolitical outcomes. For example, Rasheed et al. (2019) and Purcel (2019) showed that political stability contributes to lower CE by facilitating policy continuity, effective governance, and environmental regulation. Rasheed et al. (2019) found that political stability significantly improves environmental performance in Pakistan. Purcel (2019) found that environmental benefits depend partly on the level of institutional development. This shows the non-linearity between political stability and environmental outcomes. Agheli and Taghvaee (2022) showed that in Asian economies, political stability brings environmental sustainability. Previous studies also diverted from political stability to institutional quality (IQ). For example, Sabir et al. (2020) found that stronger IQ mitigates environmental degradation in South Asia. Azam et al. (2021) showed that IQ contributes to sustainable development in lower-middle-income economies. Nguyen et al. (2021) showed that IQ improves environmental sustainability. These findings emphasize that environmental outcomes depend not only on economic and technological factors but also on the capacity of institutions to formulate and enforce effective policies. Moreover, recent research questioned the conventional assumption that political and environmental systems operate primarily in one direction. For instance, Sofuoğlu and Ay (2020) found that climate change causes political instability. They provide evidence of a bidirectional relationship between environmental and political systems and argue that environmental degradation increases competition over scarce resources and places additional demands on already constrained institutions. Therefore, environmental shocks may not simply represent ecological challenges but generate political and institutional pressures.

More recent literature examined geopolitical risk (GPR) as a determinant of environmental sustainability. Wang et al. (2022) identified a bidirectional relationship between GPR and CE in China. They suggested that geopolitical tensions and environmental degradation can reinforce one another. Hu et al. (2022) showed that geopolitical conditions influence global energy security in developing economies. Nguyen et al. (2023) argued that geopolitical tensions hinder progress toward the Sustainable Development Goals. Zhang and Shi (2023) showed that GPR constrains financial development and sustainable economic growth. Literature also highlighted the channels through which geopolitical uncertainty causes environmental degradation. For instance, Sweidan (2022), Ding et al. (2023), Safi et al. (2023) and Bashir et al. (2023) reported that geopolitical tensions increase CE and broader environmental stress by disrupting energy markets, increasing dependence on fossil fuels, and delaying the transition toward cleaner energy sources. Moreover, the literature highlighted the role of governance in addressing the linkages between geopolitical and environmental pressures. Depren et al. (2024), Cui et al. (2024), and Dunyo et al. (2024) found that political stability, institutional quality, and research and development weaken the adverse environmental consequences of geopolitical and economic policy uncertainty. Khan et al. (2023) reported that GPR and militarization contribute to environmental degradation. Dunyo et al. (2024) demonstrated that political uncertainty increases the environmental consequences of energy consumption.

Renewable energy represents another important link between ES and geopolitics. The transition toward renewable energy reduces CE and ensures energy security by diversifying its sources. Liu et al. (2023) found that GPR has a dual effect on renewable energy investment. While uncertainty can discourage investment by increasing market risks, it can also encourage energy diversification and reduce dependence on conventional energy sources. This suggests that the effect of geopolitical uncertainty on energy transition depends substantially on the policy environment and institutional response. The effectiveness of renewable energy development also depends on supportive institutions, investment, and financial conditions. Chien et al. (2021) showed that REC, ecological innovation, environmental taxation, and green growth contribute to lower CE. Nguyen et al. (2021) emphasized the importance of IQ in supporting ES. However, geopolitical uncertainty can restrict the investment required for the energy transition. Le et al. (2021) found that GPR discourages corporate investment in developing Asian economies, while Rumokoy et al. (2023) reported comparable effects in Australia's mining sector. Financial markets provide an additional transmission channel. Tang et al. (2023) showed that geopolitical threats and economic policy uncertainty influence green bond returns, potentially affecting the financing of renewable energy projects. Zhang et al. (2023) argue that GPR generates persistent volatility in green finance and renewable energy markets. Wang et al. (2024) evidence that geopolitical threats, military conflicts, and GPR can impede energy transition across countries.

Research Gap

Despite these advances, important gaps remain in the literature. First, existing studies overwhelmingly treat geopolitics as determinants of ES, while comparatively little attention is given to the reverse relationship. Second, much of the literature measures geopolitics through GPR, conflict, militarization, or political instability. Limited attention has been given to governance-based indicators like control of corruption as a measure of geopolitical conditions. Third, empirical evidence for South Asia remains limited, despite the region's substantial environmental vulnerability, dependence on climate-sensitive resources, and geopolitical importance. The present study, rather than examining how geopolitical conditions influence environmental sustainability, investigates whether environmental pressures can shape geopolitical governance. Specifically, CE and WS are used to capture important dimensions of ES. CC is used as a proxy for geopolitical governance. By focusing on South Asian economies, the study contributes region-specific evidence to a literature that has largely emphasized the environmental consequences of geopolitics. More importantly, it extends the existing debate from a one-way relationship toward a broader understanding in which ES and geopolitical governance may influence one another.

Data and Methodology

Data

South Asia is confronted with severe transboundary environmental challenges like Himalayan glacier melt, river degradation, and climate-induced migration. These challenges are further intensified by rising energy demand, fossil fuel dependence, and unequal hydropower resources. They also interact with persistent geopolitical rivalries, particularly among India, Pakistan and China, as well as growing external influence through initiatives such as China's Belt and Road Initiative. Therefore, to study the underlying hypotheses, we take South Asia as a sample case. Seven (Pakistan, India, Bangladesh, Sri-Lanka, Nepal, Bhutan, and Maldives) out of eight countries are selected based on data availability over the period from 1996 to 2024. As CC data are available from 1996 onward, the study uses 1996 as the starting year. Similarly, 2024 is the latest year for which data on all selected variables are available from the World Development and Governance Indicators (WDI/WGI) (see Table 1).

CC is employed as a proxy for geopolitics, following the governance-based perspective adopted in recent studies (Zelikow et al., 2020). According to the Worldwide Governance Indicators (WGI), it measures the extent to which public power is exercised for private gain, encompassing both petty and grand corruption as well as state capture by elite interests. The indicator ranges from −2.5 (weak governance) to +2.5 (strong governance). Following earlier literature like Polas et al. (2023) and Woolan et al. (2023), this study proxies environmental degradation via CE (CO_2 emissions). Given the growing energy demand in South Asian economies, it provides an appropriate measure of environmental performance. We also used WS as a second proxy of environmental degradation. It is the ratio of total freshwater withdrawals to total renewable freshwater resources after accounting for environmental flow requirements. REC is measured as the percentage share of renewable energy in total final energy consumption. It reflects the extent to which an economy relies on clean energy sources rather than conventional fossil fuels. Higher renewable energy consumption contributes to environmental sustainability by reducing greenhouse gas emissions, improving air quality, and supporting low-carbon economic development. Beyond its environmental benefits, it also has important geopolitical implications. For example, reducing dependence on imported fossil fuels and diversifying energy sources, greater renewable energy adoption enhances energy security, strengthens strategic autonomy, and reduces vulnerability to external geopolitical shocks. Therefore, it is included as an important variable linking energy transition, environmental sustainability, and geopolitical outcomes. Gross Domestic Product per Capita (GDPPC), measured in current US dollars, represents the average economic output per person and serves as an indicator of a country's level of economic development. Unlike constant-price measures, GDPPC at current prices reflects prevailing market exchange rates and is influenced by both inflation and exchange rate movements. In the case of the environmental hypothesis, it captures the scale effect of economic activity on resource consumption, energy demand, and environmental quality. In geopolitical studies, it reflects national economic strength and international influence

Table 1

Variable, Description and Source

Variable Name	Description	Source
Control of Corruption (CC)	This study takes the measurement scale of CC from WGI, which is the estimate (Index Score) that ranges from approximately −2.5 to +2.5. The stronger the value, more is the control of corruption and vice versa.	WGI
Carbon dioxide emissions (CE)	Carbon dioxide (CO2) emissions (total) excluding LULUCF (% change from 1990)	WDI
Water stress (WS)	Level of water stress: freshwater withdrawal as a proportion of available freshwater resources	WDI

Renewable energy consumption (REC	Renewable energy consumption (% of total final energy consumption)	WDI
GDP per capita (GDPPC)	GDP per capita (current US$)	WDI

Methodology

Descriptive Statistics

Descriptive statistics show the distributional properties of the variables, as shown in Table 2. The table revealed that, based on 203 observations, the results are considerable heterogeneity across the sample. CC has a mean of 0.67 with a standard deviation of 0.331. It is evident for a moderate IQ with relatively low variation. GDPPC appears with a mean of 1,474.41 and a high standard deviation of 1,705.62. This reflects a substantial income disparity among the selected South Asian countries. REC averages 56.09%, with a standard deviation of 28.62, which signifies the differences in countries' energy mixes, ranging from 1.20% to 95.92%. The WS appears with a mean of 42.60 and a standard deviation of 42.53. It is evident the uneven water resource conditions across the region.

Table 2

Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
CC	203	.67	.331	.053	1.497
GDPPC	203	1474.407	1705.623	-.794	8601.632
REC	203	56.088	28.618	1.195	95.92
CE	203	.816	.731	.05	3.68
WS	203	42.598	42.532	1.394	122.673

Correlation Matrix

The correlation matrix presents the pairwise linear relationships among the variables. It offers an insight into the direction and strength of associations before formal econometric estimation. The coefficients range between -1 and +1, where positive values indicate a direct relationship and negative values suggest an inverse association. Table 3 shows the correlation matrix, which suggests that there is low to moderate to high correlation amongst the variables under study.

Table 3

Correlation Matrix

Var	CC	GDPPC	REC	CE	WS
CC	1.000				
GDPPC	-0.085	1.000			
REC	0.216	-0.582	1.000		
CE	-0.093	0.882	-0.696	1.000	
WS	-0.277	-0.092	-0.153	0.013	1.000

Cross-Sectional Dependence (CSD) and Slope Homogeneity

The global economy is interconnected; hence, shocks originating in one country or region can transmit and affect others through multiple channels. Such interconnections often lead to cross-sectional dependence (CSD) in panel data, where the error terms across units are correlated rather than independent. Ignoring it in analysis may result in biased and inconsistent estimations. Therefore, to account for this residual dependency, we utilized the CSD test proposed by M. Hashem Pesaran (2015). It is widely recognized for its robustness in detecting weak and strong forms of dependence across panel units. Table 4 displays the CSD, which rejects the null hypothesis of no CSD in the model. Therefore, we conclude that entities are interdependent. Moreover, to test homogeneity, Pesaran and Yamagata (2008) suggested a slope homogeneity test. For large samples, they recommend the Δ test, and for smaller samples, the Δadj test is suggested. This study used Pesaran and Yamagata (2008) tests to check the nature of slope (see Table 4 for details).

Table 4

	CD	CDw	CDw+	CD*	CD
CC	2.350	-1.630	27.350	1.310	
	(0.019)	(0.103)	(0.000)	(0.189)	
GDPPC	19.970	-3.540	87.980	-2.330	19.970
	(0.000)	(0.000)	(0.000)	(0.020)	(0.000)
REC	21.810	-3.210	96.740	-14.240	21.810
	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
CE	22.300	-3.180	99.000	3.330	22.300
	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
WS	2.630	-2.440	58.930	5.350	2.630
	(0.009)	(0.014)	(0.000)	(0.000)	(0.009)
Slope Homog.	Delta:	6.36	(0.000)	Adj. Delta:	7.410 (0.000)

CSD and Slope Homogeneity Analysis

Panel unit, VIF and Tolerance

The stationarity test is important because estimating non-stationary data gives spurious results. In past studies conducting panel data analysis, Pesaran and Levin-Lin-Chu tests were unable to overcome CSD and heteroscedasticity (Şahin, L. (2021). Pesaran cross-section augmented (CIPS) and (CADF) tests are applied to overcome the drawbacks of these techniques. The outcomes of the CIPS are shown in Table 5 revealed that variables like CC, REC, and CE do not reject the null hypothesis of unit root at levels and, therefore, we take them at first difference where these variables become stationary. However, GDPPC and WS are stationary at levels, i.e., I(0). Similarly, the application of the CADF test confirms I(1) for CC, REC, CE, and I(0) for GDPPC and WS. This mixed order of integration validates the suitability of the data for cointegration-based estimation like CS- ARDL. The outcome of VIF shows that the individual values are well below the conventional threshold of 5 for all the selected variables, whereas the mean is 1.662. Hence, we concluded for no multicollinearity.

Table 5

Unit Root, VIF and Tolerance Analysis

Variables	CIPS		CADF				
	I (0)	I (1)	I (0)	I (1)	Decision	VIF	1/VIF
CC	-2.143	-5.37***	-2.576	-3.58***	I (1)		
GDPPC	-2.588**	----	-2.676**	----	I (0)	2.509	.182
REC	-1.382	-5.18***	-1.306	-3.641	I (1)	1.555	.08
CE	-1.134	-5.17***	-1.076	-2.885**	I (1)	2.198	.139
WS	-3.20***	-------	-3.28***	-------	I (0)	1.409	.71
Mean						1.662	

Note: ***/**/* shows 1%,/5%/10% level of significance

Cointegration

The Westerlund (2007) ECM-based panel cointegration tests provide robust evidence of long-run cointegration among the variables. Therefore, we reject the null hypothesis of no cointegration (H0). More specifically, as can be seen in Table 6, three out of four statistics evident for the existence of long-run cointegration.

Table 6

Cointegration Analysis

	Dep. Var. (CC)	
	Value	**P-Value**
G_t	-5.083	(0.006)
G_a	-2.475	(1.000)
P_t	-3.033	(0.003)
P_a	-4.086	(0.000)

Long Run and Robust Estimation Technique

To analyse panel data, a wide range of econometric techniques has been proposed and extensively applied in the existing literature. Nevertheless, when CSD and slope heterogeneity are present, conventional first-generation estimators tend to produce biased, inconsistent, and potentially misleading inference due to their restrictive assumptions of cross-sectional independence and parameter homogeneity. To address these issues, second-generation panel econometric approaches are used. It accounts for CSD and heterogeneous slope dynamics. In the present study, given that the variables are integrated of mixed order of integration, have CSD, and display slope heterogeneity, the Cross-Sectionally Augmented Autoregressive Distributed Lag (CS-ARDL) model is deemed most appropriate. It allows for the consistent estimation of both long-run equilibrium relationships and short-run dynamic adjustments in the presence of unobserved common factors that may simultaneously influence all cross-sectional units (Qamruzzaman, M. et al., 2025). Moreover, it addresses endogeneity concerns arising from simultaneity, omitted variables, and dynamic feedback effects, as highlighted by Pesaran (2015). Another key advantage of this approach is its ability to incorporate an ECM, which captures the speed at which the system converges back to long-run equilibrium following a short-run shock or disequilibrium.

Accordingly, the general form of the CS-ARDL model can be specified as follows:

$$dX_{it} = \text{©}_i + \text{¢}_i\,(X_{it-1} + \lambda_i Y_{it} + \pi_{1i}\overline{X_{t-1}} + \pi_{2i}\overline{Y_{t-1}}) + \sum_{j=1}^{p-1}\tau_{ij}\,dX_{it-j} + \sum_{j=0}^{q-1}\text{£}_{ij}\,dY_{it-j} + \Omega_{1i-j}\overline{dX_t} + \Omega_{2i}\overline{dY_t} + \varepsilon_{it} \quad (1)$$

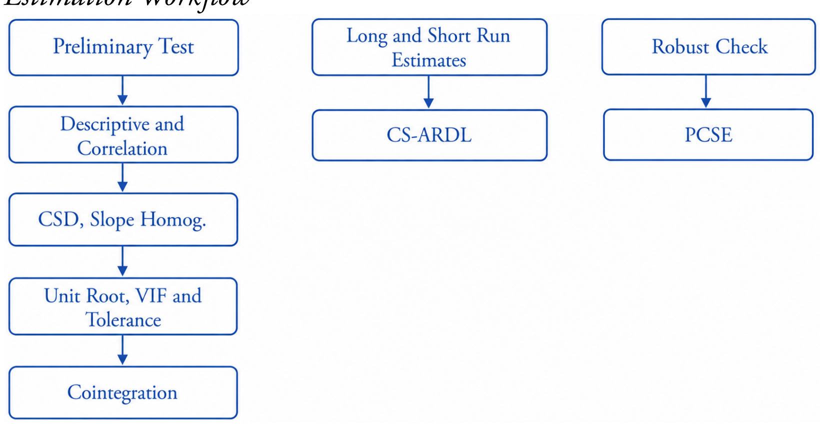
"it" is panel units. X and Y are regressand and regressors, respectively. $\overline{X_{t-1}}$ and $\overline{Y_{t-1}}$ are the lagged representations of dependent and independent variables. The short-run influence is captured through $\overline{dX_t} + \overline{dY_t}$ while the error term is represented by epsilon "ε_{it}".

Robust Check

We employed PCSE as a robustness check for the results obtained from the CS-ARDL model. PCSE is used to confirm whether the statistical significance and direction of estimated relationships remain stable under an alternative estimation framework. This dual approach strengthens the credibility and robustness of the empirical findings, ensuring that results are not sensitive to a single econometric specification.

Figure 1

Estimation Workflow



Results and Discussion

Long Run Estimates

Results displayed in Table 7 show that the estimated coefficient of CE is negative (-0.207) and statistically significant (p = 0.003). It suggests that increasing environmental degradation is associated with weaker CC over the sample period. These results support the argument of (Azimi et al., 2023) that poor governance and corruption reduce the effectiveness of environmental regulations and weaken enforcement mechanisms, which ultimately lead to CE. South Asia is confronted with institutional capacity constraints, political interference, and limited accountability, which allow firms to circumvent environmental regulations through corrupt practices. Therefore, economies facing higher CE show evident weaker governance quality, as corruption undermines environmental compliance and enforcement. As argued by Cavalheiro et al. (2025), the findings of this study show that ES and governance quality are mutually reinforcing. This implies that, to achieve long-term environmental objectives, corruption must be controlled effectively.

WS is positive and significant. Its magnitude (1.062) shows that worsening WS improves the CC in the long run. Although the results are counterintuitive but can be explained by the increasing institutional response to water crises across South Asia. As argued by Grafton et al. (2025), Matimolane & Mathivha (2025), and Evaristo et al. 2023), severe water shortages attract greater public attention, international donor support, and stronger government intervention. Therefore, encourage the implementation of more transparent water governance systems, stricter regulatory oversight and enhanced accountability in water resource management. Countries with persistent water stress should therefore strengthen institutional mechanisms to ensure equitable allocation of water resources and reduce opportunities for corruption in irrigation systems, water distribution, and public infrastructure projects (Matimolane & Mathivha, 2025). Moreover, in South Asia, WS represents a national security and geopolitical concern. It prompts governments to improve governance structures to manage transboundary water resources more effectively. Thus, the positive coefficient suggests that environmental pressure may stimulate institutional reforms that ultimately strengthen corruption control over time.

GDPPC has a negative (-0.530) and statistically significant (p = 0.012) influence on CC. The results indicate that a one-unit increase in GDPPC decreases the CC index by approximately 0.211 units. These results show that economic growth alone does not translate into stronger governance institutions in South Asia. In line with the findings of Afonso et al. (2022), the results show that although higher income levels generally provide governments with greater fiscal resources to strengthen institutions, the economic expansion in South Asia has not been accompanied by proportional improvements in governance quality. Moreover, the result of this study reflects the institutional realities of many South Asian countries where high-growth sectors, infrastructure development, and natural resource allocation continue to suffer from governance weaknesses.

The coefficient of REC is also negative (-0.954) and statistically significant (p = 0.019). It suggests that higher REC controls corruption in our sample region. These results support the argument that renewable energy drives sustainable development (Gayen et al., 2024). The expansion of renewable energy in South Asia depends heavily on government subsidies, as it is in the early stages of development where regulatory institutions are still evolving. Therefore, the expansion of renewable energy alone does not automatically improve governance unless accompanied by transparency and accountability.

Short-Run Results

The short-run coefficient of CE is negative but statistically insignificant. It shows that short-term fluctuations in emissions do not significantly affect corruption control. Similarly, WS is positive but statistically insignificant. Although the long-run results reveal a strong positive relationship, short-term variations in WS do not immediately influence CC. Hence, the governance benefits associated with WS are long-term rather than immediate. The short-run coefficient of GDPPC is positive and statistically significant. It suggests that temporary increases in economic activity provide governments with additional fiscal resources to improve administrative efficiency. The coefficient of REC is negative and marginally significant. It indicates that short-term changes in REC have limited immediate effects on CC. The ECM is negative (-0.792) and highly significant (p = 0.000). It confirms the existence of a stable long-run equilibrium relationship among the variables. It shows that approximately 29.9% of deviations from the long-run equilibrium are corrected within one year.

The diagnostic statistics indicate that the estimated CS-ARDL model provides a satisfactory representation of the data. The overall F-statistics (12.32) confirms that the explanatory variables are jointly significant in explaining variations in CC. The model explains approximately 43% of the variation in CC, as shown by the R-squared value of 0.43.

Table 7

Long Run and Shor Run Estimates

Long Run Estimates	Variable	Coefficient	P-Value
	CE	-0.207	0.003
	WS	1.062	0.005
	GDPPC	-0.530	0.012
	REC	-0.954	0.019
Shor Run Estimates			
	ΔCO2	-1.492	0.990
	ΔCRW	0.005	0.612
	ΔGDPPC	0.174	0.037
	ΔREC	-0.094	0.196
	ECM	-0.792	0.000
Diagnostic Tests	F(105, 91)	12.32	0.000
	R-squared	0.43	

Robust Check

For robustness of the model, we re-estimated the equation using the PCSE estimator. It is best suited to account for heteroskedasticity, serial correlation, and CSD. The findings of PCSE are in table 8 which confirm the main findings of the study. The results show that CE is positive and significant against CC. WS continues to exert a positive and significant influence on CC. It shows that growing WS promotes stronger institutional responses, improved resource governance, and greater accountability. GDPPC is negative showing that economic growth alone is insufficient to improve governance. REC remains negative and statistically significant, showing that the expansion of REC creates governance challenges if regulatory and monitoring mechanisms remain weak. The Wald Chi-square statistics confirm the overall significance of the model, while the R-squared value of 0.30 indicates that the explanatory variables account for a reasonable proportion of the variation in CC.

Table 8

Robust Check: PCSE

Variable	Coeff	P-value
CE	0.521	0.000
WS	1.989	0.000
GDPP	-0.251	0.081
REC	-0.0469	0.000
R-Sq.	0.30	
Wald chi2	102.13	0.000

Conclusion, Policy Implications and Limitation

Conclusion

This study examined the role of environmental sustainability (ES) in shaping geopolitical governance in South Asia. ES is proxy via CE and WS while geopolitical governance through CC. Unlike previous literature that examines the role of geopolitics in ES, this study reverses the analytical perspective and investigated the role of ES in geopolitical outcomes.

Findings of the study revealed that CE weakens control of corruption. It shows that environmental degradation is caused because of weak institutions that failed in implementation of regulations. WS was found positive against CC in the long run. It shows that severe WS encourages governments to strengthen institutional oversight, improve water governance, and implement more transparent resource allocation mechanisms. GDPPC was found negative in long-run. It suggests that economic growth without corresponding institutional reforms create opportunities for rent-seeking and regulatory capture. REC exhibits a negative relationship with CC. It implies that REC alone cannot improve governance unless accompanied by transparent regulatory frameworks and institutional accountability. In the short run, only GDPPC significantly improves governance, whereas the effects of CE and WS emerge gradually over time. The robustness analysis confirms the stability of these relationships.

Policy Implications

Based on the findings of this study, several important policy implications are provided for South Asian economies:

- There is a need to integrate ES objectives into broader governance and anti-corruption strategies rather than treating them as separate policy areas.
- Since WS appears to encourage institutional improvements, governments should prioritize integrated water resource management, transboundary water cooperation and transparent allocation mechanisms to improve both ES and governance.
- Renewable energy policies should be accompanied by transparent procurement procedures, competitive bidding systems and independent regulatory oversight to minimize corruption risks associated with renewable energy investments.
- Economic growth strategies should be complemented by institutional reforms that improve accountability and anti-corruption enforcement to ensure that development translates into better governance.

Limitations of the Study

Despite its contributions, the study has several limitations. For example, the analysis is limited to seven South Asian countries, which may restrict the generalizability of the findings to other regions with different institutional and environmental characteristics. Second, CC is used as a proxy for geopolitical governance. Although theoretically justified, it is a multidimensional concept that could also be represented by other proxies like political stability, government effectiveness, regulatory quality, geopolitical risk, or state capacity. Therefore, future studies may address these limitations.

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