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Original Article

Determinants of Carbon Dioxide (CO2) Emissions in South Asia: Empirical Evidence

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Abstract: *The study seeks to examine the short-run determinants of Carbon Dioxide (CO_2) emissions across the selected South Asian countries, emphasizing the region's heterogeneity in economic growth, demographic pressures, and energy structures. Utilizing annual data from 1990 to 2020, and applying the Autoregressive Distributed Lag (ARDL) approach, the analysis uncovers significant emission persistence and varying impacts of GDP per capita, population dynamics, and energy consumption patterns on emissions. Moreover, the use of fossil fuels consistently exacerbates emissions growth across economies. Besides, access to electricity and clean cooking fuels usually shows limited immediate effects on the emission levels. Collectively, the findings reveal the importance of country-specific energy transitions and policy measures aimed at promoting the usage of renewable energy and improving energy efficiency to achieve sustainable development and environmental goals in South Asian regions.*

Keywords: *Carbon Dioxide (CO_2) Emissions, Economic Growth, Fossil Fuels, Renewable Energy Consumption, South Asia.*

I. INTRODUCTION

The South Asian nations embody a series of heterogeneous characteristics in the form of cultural and linguistic diversities, diversified economic and social structures, differentiated energy structures, and linked geographies. Despite being part of a similar yet broad region, the multiple countries differ substantially in terms of income levels, population sizes, energy mix, and most importantly, the respective development trajectories. The vested diversity allows for meaningful cross-country comparison, while at the same time taking due care of the regional coherence. Furthermore, the countries also exhibit varying degrees of dependence on fossil fuels as well as renewable energy, making them particularly relevant for examining the short-run emission dynamics prevalent, particularly in the developing and transition economies.

South Asia constitutes a strategically significant sub-region of the developing world, comprising Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka- countries that are geographically interconnected and historically linked, collectively accounting for a substantial share of the global population, while exhibiting marked heterogeneity in income levels, demographic pressures, institutional capacity, and energy structures (Bhattacharjee & Haldar, 2015; Devarajan & Nabi, 2006). Over the past few decades, South Asian economies have experienced sustained economic expansion driven mainly by industrialization, urban population growth, infrastructure development, and increasing integration into global markets. However, this growth has been largely energy-intensive and uneven, with several countries relying heavily on fossil fuels to support production and consumption activities (Apergis & Ozturk, 2015; Narayan & Narayan, 2010). These structural characteristics place South Asia in a relevant and analytically rich setting for examining the growth–environment nexus within developing and transitioning economies.

Parallel to the economic expansion levels, the regions have also witnessed a steady rise in Carbon Dioxide (CO_2) emissions over time, raising concerns pertaining to environmental sustainability and long-term development outcomes. Multiple empirical evidences suggest that factors such as population growth, rising income levels, fossil fuel consumption, urbanization, as well as trade expansion have collectively contributed towards increasing the emission levels across the South Asian countries, although the magnitude and direction of influence vary by country and over time period (Ahmed et al., 2016; Zeshan & Ahmed, 2013). Thus, it becomes quite essential to understand the short-run dynamics of CO_2 emissions on account of the region's developmental diversity and differentiated energy transitions. Against this backdrop, the present study seeks to identify the key determinants of CO_2 emissions in South Asia, with a focus on how economic growth, demographic factors, and energy consumption shape short-run emission behavior across the countries.

II. LITERATURE REVIEW

At the global stage, South Asia has emerged as one of the most dynamic, relevant, as well as environmentally stressed regions. When the developing nations are taken into consideration, the region is earmarked with rapid economic growth, mounting population pressures, evolving structural transformations, as well as escalating energy demands. In addition, the

economic growth in the region is driven mainly by key factors such as industrial expansion, capital accumulation, infrastructure development, urbanization, as well as trade integration; however, growth outcomes continue to remain uneven across the economies (Aspergis & Ozturk, 2015; Bhattacharjee & Haldar, 2015; Deverajan & Nabi, 2006). Besides, factors such as institutional quality, governance constraints, and macroeconomic stability hinder the sustainability of these growth trajectories (Mehmood et al., 2022).

Distinguished researchers in the contemporary timeframe have laid emphasis on understanding the growth-environment nexus, particularly with regard to carbon dioxide (CO_2) emissions. A major set of literature finds that factors such as economic growth, population expansion, and fossil-fuel-based energy consumption exert a significant positive influence on emissions in the South Asian Economies, thereby reflecting the scale effects and structural dependence on carbon-intensive production systems (Ahmed et al., 2016; Zeshan & Ahmed, 2013; Narayan & Narayan, 2010). Apart from that, population growth also amplifies environmental pressures by intensifying energy demand and resource use, primarily in the nations that are densely populated, such as India, Pakistan, and Bangladesh (Ahmed et al., 2020; Keho, 2017).

Evidence on the Environmental Kuznets Curve (EKC) hypothesis for South Asia denotes mixed results. While certain studies observe an inverted U-shaped relationship between income and emissions, revealing potential environmental improvements beyond specified income thresholds, other studies find persistent environmental degradation alongside growth, indicating the absence of a clear turning point (Sadiq et al., 2021; Jaunky, 2011). Besides, multiple contemporary studies have emphasized the mitigating role of renewable energy adoption, energy efficiency, institutional quality, and regulatory effectiveness in decoupling economic growth from emissions (Mehmood et al., 2022; Zhang & Liu, 2019; Nasreen et al., 2017). Overall, the literature reveals a complex, country-specific growth-environment relationship in South Asia, emphasizing the need for context-specific, energy-focused, and institutionally grounded policy interventions.

III. OBJECTIVES

- To examine the short-run determinants of Carbon Dioxide (CO_2) emissions in selected South Asian Countries.
- To assess the short-run impact of energy structures on Carbon Dioxide (CO_2) emissions in South Asia.

IV. METHODOLOGY

The study utilizes annual time series data retrieved from the World Development Indicators (WDI) database maintained by the World Bank. The database is primarily used in empirical environmental as well as development studies on account of its consistency, comparability, and diversified country coverage. The period of analysis varies slightly across the countries depending on key factors such as data availability and reliability. However, the period spans from 1990 to 2020. The Carbon Dioxide emissions are used as the dependent variable, demonstrating the environmental pressure arising from economic activity as well as energy use. The key explanatory variables include GDP per capita, population, renewable energy consumption, fossil fuel consumption, access to electricity, and access to clean cooking fuels, which have been selected to capture the major economic, demographic, as well as energy-related drivers of emissions.

Prior to the estimation and associated analysis, the unit root properties of all the variables were examined using the Augmented Dickey- Fuller (ADF) tests to determine the order of integration. The variables were found to be non- stationary at both levels, and first differences were excluded from the model to avoid the emerging econometric inconsistency. In multiple countries, population as well as access to clean cooking fuels were dropped on account of weak stationarity properties or unstable dynamic behavior. The Autoregressive Distributed Lag (ARDL) approach is adopted for the empirical analysis, which is suitable for small samples and allows for the inclusion of variables of order I(0) and I (1). Since the bounds test for cointegration was not valid in most of the cases, the analysis primarily focuses on short-run dynamics, capturing the immediate as well as lagged effects of economic growth, population change, and energy structure on the Carbon Dioxide (CO_2) emissions.

V. FINDINGS

Table 1: Abbreviations used for the variables.

Sl. No.	Abbreviations	Explanation
1.	CO_2	Carbon Dioxide Emissions
2.	GDPPC	GDP per capita
3.	Popn	Population
4.	RenewEN	Consumption of Renewable Energy
5.	Fossil Fuels	Consumption of Fossil Fuels
6.	Elec Access	Access to Electricity

A) Afghanistan

The following regression equation has been adopted for Afghanistan.

$$CO_{2t} = \alpha + \beta_1 CO_{2t-1} + \beta_2 GDPPC_t + \beta_3 GDPPC_{t-1} + \beta_4 Popn_t + \beta_5 Popn_{t-1} + \varepsilon_t$$

The short run ARDL analysis for Afghanistan indicates a prolonged prevalence of Carbon Dioxide (CO_2) emissions, as revealed by a positive and statistically significant coefficient of the respective lagged emissions. This critically puts forward the notion that the current emission levels are strongly influenced by the past emission patterns, thereby demonstrating slow adjustment in energy use and production structures. Additionally, GDP per capita influences the emission levels positively in its lagged form, which states that economic growth also contributes to environmental pressure, however, with a temporal delay rather than an immediate effect. Furthermore, the population effects are mixed, and they tend to remain largely insignificant in the short run, which indicates that demographic pressures do not necessarily translate sporadically into higher emissions; however they may operate through the delayed scale effects. Overall, the broad findings in the case of Afghanistan suggest that the emissions are mainly driven by key factors such as emission inertia and delayed economic influences, thereby demonstrating the dominance of short-run dynamics over long-run equilibrium adjustments in explaining the emission behavior.

B) Bangladesh

The following regression equation has been adopted for Bangladesh.

$$CO_{2t} = \alpha + \beta_1 CO_{2t-1} + \beta_2 GDPPC_t + \beta_3 GDPPC_{t-1} + \beta_4 GDPPC_{t-2} + \beta_5 Popn_t + \beta_6 Popn_{t-1} + \varepsilon_t$$

The short-run ARDL analysis for Bangladesh critically underscores a strong dominance of Carbon Dioxide (CO_2), as reflected by the positive yet highly significant coefficient of the lagged emissions. This indicates that the current emissions in Bangladesh are heavily influenced by the past emission trajectories, thereby further revealing inertia in energy consumption and production structures. Additionally, the GDP per capita also exhibits a dynamic short-run relationship with emissions. Although the contemporary economic growth significantly drives the CO_2 Emissions, the first lag shows a significant negative effect, followed by a positive yet significant second lag. This prevalent alternating pattern suggests short-run adjustment dynamics, in which initial efficiency gains or the structural shifts temporarily offset emissions before the scale effects start dominating. Furthermore, population effects are comparatively weaker in the immediate period but become significant in the lagged term, implying that the demographic pressures impact the emissions with a delay. Overall, the findings reveal that the CO_2 emissions in Bangladesh are primarily driven by factors such as emission persistence and short-run economic growth dynamics, while demographic pressures exert a gradual yet systematic reinforcing effect rather than an immediate impact.

C) Bhutan

The following equation was adopted for Bhutan:

$$CO_{2t} = \alpha + \beta_1 CO_{2t-1} + \beta_2 GDPPC_t + \beta_3 GDPPC_{t-1} + \beta_4 GDPPC_{t-2} + \beta_5 Popn_t + \varepsilon_t$$

In the case of Bhutan, there exists a strong prevalence of Carbon Dioxide (CO_2) emissions. As reflected by the positive and statistically significant coefficient of the lagged CO_2 emissions. This further suggests that the past emission levels also influence the current emission levels, thereby revealing inertia in energy use and production structures. Additionally, the GDP per capita also shows a dynamic and non-linear short-run relationship with the emissions. While the contemporary effect of economic growth exacerbates the emissions, the first lag shows a mitigating effect, followed by a renewed positive influence in the second lag. This continuous alternating pattern categorically underpins short-term adjustment mechanisms in Bhutan's growth – environment trajectory, in which the initial expansion raises the emission levels but subsequent adjustments partially offset them before the pressures re-emerge. Furthermore, the population exerts a negative yet significant contemporaneous effect on the emissions, indicating that demographic expansion in Bhutan does not necessarily translate into higher emission intensity in the short run, mainly due to low-carbon livelihoods and strong environmental governance. Overall, it can be stated that the emissions in Bhutan are shaped more by the growth dynamics and emission persistence than by the demographic pressure.

D) India

$$CO_{2t} = \alpha + \beta_1 CO_{2t-1} + \beta_2 CO_{2t-2} + \beta_3 GDPPC_t + \beta_4 Popn_t + \beta_5 Popn_{t-1} + \beta_6 Popn_{t-2} + \beta_7 RenewEN_t + \beta_8 FossilFuels_t + \beta_9 ElecAccess_t + \varepsilon_t$$

In the case of India, the Carbon Dioxide (CO_2) emissions are strongly influenced by economic growth and energy structures rather than by electrification alone. The GDP per capita exerts a positive and highly significant sporadic effect on the CO_2 emissions, thereby indicating that the short-run economic expansion in India remains energy and emission-intensive. Additionally, the emission persistence is also evident through the significant second lag of CO_2 emissions, thereby reflecting inertia in industrial activities and fossil fuel-based energy systems. Moreover, the population effects are mixed: while the immediate impact is weak, the lagged population terms are significant with alternating signs, thereby suggesting that short-run demographic adjustment mechanisms rather than a monotonic scale effect. Moreover, the renewable energy consumption plays a mitigating role, significantly reducing emissions, thereby demonstrating the effectiveness of India's renewable transition in the short run. On the other hand, fossil fuel consumption significantly drives emissions, reaffirming its critical role in India's energy consumption and emission profile. Besides, access to electricity continues to remain statistically insignificant, thereby

implying that the recent efforts in enhancing electrification have not exacerbated emissions, mainly due to factors such as efficiency improvements and cleaner generation sources. Thus, it can be stated that the emissions in India are driven primarily by the dynamics associated with economic growth, accompanied by dependence on fossil fuels.

E) Maldives

The following equation has been adopted for the Maldives:

$$CO_{2t} = \alpha + \beta_1 CO_{2t-1} + \beta_2 Popn_t + \beta_3 GDPPC_t + \beta_4 GDPPC_{t-1} + \beta_5 RenewEN_t + \varepsilon_t$$

In the Maldives, the persistence of emissions and short-run economic adjustments, accompanied by structural energy transitions, influences the Carbon Dioxide Emissions. The lagged CO_2 emissions term is positive and statistically significant, suggesting strong inertia in the emission levels, reflecting gradual adjustment in energy consumption patterns. Additionally, population exhibits a positive yet statistically weak effect on emissions, implying that demographic expansion contributes marginally to the emissions, mainly on account of services and tourism-oriented industry rather than heavy industries. Moreover, the GDP per capita displays a delayed negative impact on the emission levels, with the lagged income term being statistically significant. This indicates that income growth may induce short-run efficiency gains, technological improvements, or shifts towards less carbon-intensive activities instead of sporadic emission escalations. Furthermore, the consumption of renewable energy exerts a negative effect, revealing its emission-mitigating role even in the short run. Overall, the findings suggest that the emissions in the Maldives are shaped more by the past emission dynamics and short-run efficiency adjustments than by the scale effects of growth.

F) Myanmar

The following equation was adopted for Myanmar:

$$CO_{2t} = \alpha + \beta_1 CO_{2t-1} + \beta_2 CO_{2t-2} + \beta_3 Popn_t + \beta_4 Popn_{t-1} + \beta_5 Popn_{t-2} + \beta_6 GDPPC_t + \beta_7\, GDPPC_{t-1} + \beta_8 RenewEN_t + \beta_9 RenewEN_{t-1} + \beta_{10} RenewEN_{t-2} + \beta_{11} FossilFuels_t + \beta_{12}\, FossilFuels_{t-1} + \beta_{13}\, FossilFuels_{t-2} + \beta_{14} ElecAccess_t + \varepsilon_t$$

A strong persistence of Carbon Dioxide (CO_2) emissions is uncovered in Myanmar, as lagged emissions exert a positive and statistically significant influence on the current emission levels, which reveals structural inertia in Myanmar's energy and production systems, where emission adjustments occur gradually instead of being sporadic. Additionally, economic growth shows a delayed effect on emissions: while contemporaneous GDP per capita is insignificant, its lagged effect is positive and significant, suggesting that growth translates into higher emissions with a time lag through energy-intensive activities such as manufacturing and transport. Furthermore, the population effects are mixed and predominantly weak in the short run, implying that demographic pressure does not directly scale emissions but operates through multiple indirect and delayed channels. Moreover, the energy structure also emerges as a critical determinant, as the consumption of renewable energy significantly curbs emissions in the contemporary timeframe, thereby aligning with the emission-mitigating role, although the positive lagged effects indicate short-run adjustment dynamics. Subsequently, fossil fuel consumption shows volatility, with alternating lag effects reflecting substitution and demand adjustments. However, access to electricity remains statistically insignificant, which uncovers a notion that electrification alone doesn't directly exacerbate short-run emissions in Myanmar.

G) Nepal

The following equation was adopted for Nepal:

$$CO_{2t} = \alpha + \beta_1\, CO_{2t-1} + \beta_2\, CO_{2t-2} + \beta_3\, Popn_t + \beta_4\, Popn_{t-1} + \beta_5\, Popn_{t-2} + \beta_6\, GDPPC_t + \beta_7\, GDPPC_{t-1} + \beta_8\, RenewEN_t + \beta_9\, RenewEN_{t-1} + \beta_{10}\, FossilFuels_t + \beta_{11}\, FossilFuels_{t-1} + \beta_{12}\, ElecAccess_t + \varepsilon_t$$

In Nepal, the Carbon Dioxide (CO_2) emissions are shaped by the demographic dynamics and the persistent energy mix, instead of immediate income effects. The ARDL results reveal that there exists delayed adjustment and structural rigidity in energy usage, as the first lag is insignificant and the second lag is positive and significant. Additionally, population also emerges as a key short-run determinant demonstrating a mixed pattern, viz., the contemporaneous and second lag effects are negative and significant, while the first lag is positive and significant. The alternating structure critically suggests the short-run demographic adjustment, i.e., phenomena in which initial population growth raises emissions through the scale effects, but it is later compensated by the behavioral changes or efficiency gains. Moreover, the GDP per capita shows a weak and marginally positive relationship with that of emissions, implying that the short-run economic expansion in Nepal doesn't strongly intensify the severity of the environmental pressure. Furthermore, renewable energy consumption significantly reduces emissions, confirming its strong mitigation role, in line with Nepal's reliance on hydropower. On the other hand, fossil fuel consumption significantly raises emissions, thereby revealing its dominance and a critical role in exacerbating short-term emissions. Besides, electricity access remains insignificant, thereby indicating that electrification alone doesn't raise emissions in the short run.

H) Pakistan

The following equation was adopted for Pakistan.

$$CO_{2t} = \alpha + \beta_1 CO_{2t-1} + \beta_2 CO_{2t-2} + \beta_3 GDPPC_t + \beta_4 GDPPC_{t-1} + \beta_5 GDPPC_{t-2} + \beta_6 RenewEN_t + \beta_7 RenewEN_{t-1} + \beta_8 FossilFuels_t + \beta_9 FossilFuels_{t-1} + \beta_{10} FossilFuels_{t-2} + \beta_{11} ElecAccess_t + \varepsilon_t$$

The short-run ARDL results of Pakistan reveal that Carbon Dioxide (CO_2) emissions are mainly driven by a culmination of economic growth, energy consumption, as well as the demographic factors. The persistence of emissions is moderate, with the second lag of CO_2 emissions being negative and statistically significant, thereby suggesting partial adjustment accompanied by short-run corrections following past emission shocks. Additionally, GDP per capita also emerges as a strong contributor towards raising the emission levels, with both the current and the lagged effects being positive and statistically significant. This reflects the dependence of the economy on the development pathways, which are intensively dependent on energy, whereby the increase in income translates into higher industrial activity, transport demand, as well as greater fossil fuel consumption. Furthermore, consumption of renewable energy plays a mitigating role in the short run, as its current effect significantly curbs emissions, although the positive lagged effect reveals adjustment dynamics in which renewable expansion falls in line with the rising overall energy demand. Moreover, fossil fuel consumption demonstrates volatility, with significant lagged effects confirming its critical role in shaping emissions. Besides, access to electricity remains statistically insignificant, revealing that electrification solely doesn't directly influence short-run emission outcomes, mainly due to inefficiencies and the heavy dependence on fossil fuels.

I) Sri Lanka

The following equation was adopted for Sri Lanka.

$$CO_{2t} = \alpha + \beta_1 CO_{2t-1} + \beta_2 CO_{2t-2} + \beta_3 GDPPC_t + \beta_4 GDPPC_{t-1} + \beta_5 Popn_t + \beta_6 RenewEN_t + \beta_7 RenewEN_{t-1} + \beta_8 RenewEN_{t-2} + \beta_9 FossilFuels_t + \beta_{10} FossilFuels_{t-1} + \beta_{11} FossilFuels_{t-2} + \beta_{12} ElecAccess_t + \varepsilon_t$$

The short run ARDL analysis for Sri Lanka categorically reveals an important adjustment dynamics in Carbon Dioxide (CO_2) emissions, with evidence of partial correction over time. The second lag of CO_2 emissions is negative and statistically significant, which indicates that short- run emission shocks tend to be adjusted downwards, thereby reflecting responsive energy use patterns or short-term policy and structural adjustments. Additionally, economic growth, measured through GDP per capita, tends to exert a significant negative contemporaneous effect on emissions, thereby suggesting that the short-run income growth in Sri Lanka is associated with key factors such as efficiency improvements, technological progress, or a shift towards less energy-intensive activities. Furthermore, population also emerges as a strong and positive determinant of emissions, revealing the crucial role of demographic pressure in driving short run emissions. Moreover, consumption of renewable energy plays a critical mitigating role, with the contemporaneous and lagged effects significantly curbing the emission levels, thereby revealing the effectiveness of the renewable energy programmes adopted by the nation. On the other hand, fossil fuel consumption raises emissions with a lag, thereby uncovering the inertia and rebound efforts in fossil-fuel energy use. Besides, access to electricity remains statistically insignificant, thereby indicating that electrification alone does not exacerbate short-run emissions.

Overall, it can be stated that, while economic growth, population change, and energy use influence the emission levels across the countries, the effects vary in direction, strength, and timing depending on the national structures and energy systems.

VI. CONCLUSION

The climate change mitigation in developing countries requires a clear understanding of how economic growth, population dynamics, and energy use interact to influence Carbon-Dioxide (CO_2) emissions. The study seeks to contribute to the understanding by examining country-specific emission patterns across selected South Asian economies. Rather than treating the region as a homogeneous block, the analysis reveals how economic stability, development pathways, and energy mix shape short-run emission outcomes in distinct ways. The key findings reveal that economic growth continues to exert environmental pressure in several countries, particularly in economies where growth continues to be closely linked to fossil fuel-based energy systems. Across the countries, energy composition emerges as the most consistent determinant of Carbon Dioxide Emissions. Renewable energy consumption is found to reduce emissions in most cases, revealing its effectiveness in the short run, while fossil fuel use remains a persistent source of emission growth, often reflecting structural dependence as well as limited short-term flexibility in energy systems. Variables related to energy access, such as electricity availability and clean cooking fuel access, generally show limited immediate impact, thereby indicating that access expansion alone doesn't guarantee environmental improvement without cleaner energy sources. Promoting the usage of renewable energy, improving energy efficiency, and gradually reducing reliance on fossil fuels are essential for aligning the development objectives with environmental sustainability.

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Appendix

Appendix 1: Afghanistan

Table 02. Short-Run ARDL Results for CO_2 Emissions in Afghanistan

Variables	Coefficient Sign	Significance
CO_2 (t−1)	Positive	**Significant**
GDPPC (t)	Positive	Insignificant
GDPPC (t−1)	Positive	**Significant**
Population (t)	Negative	Insignificant
Population (t−1)	Positive	Insignificant
Constant	—	Insignificant

Table 03. Summary of Short-Run Effects on CO_2 Emissions

Variables	Short-Run Effect	Interpretation
Lagged CO_2	Positive	Emissions show strong persistence
GDP per capita	Positive (lagged)	Economic growth increases emissions with delay
Population	Mixed	Demographic effects are gradual
Energy access variables	—	Omitted due to collinearity

Appendix B: Bangladesh

Table 04. ARDL Short-Run Regression Results for Bangladesh

Variables	Coefficient Sign	Statistical Significance
CO_2 emissions (t−1)	Positive	**Significant (1%)**
GDP per capita (t)	Positive	**Significant (1%)**
GDP per capita (t−1)	Negative	**Significant (1%)**
GDP per capita (t−2)	Positive	**Significant (1%)**
Population (t)	Negative	Marginally insignificant
Population (t−1)	Positive	**Significant (5%)**
Constant	—	Insignificant

Table 05. Summary of Short-Run Effects on CO_2 Emissions in Bangladesh

Variables	Short-Run Effect	Interpretation
Lagged CO_2 emissions	Strong positive	Emissions exhibit high persistence
GDP per capita	Mixed (dynamic)	Growth raises emissions with adjustment over time
Population	Delayed positive	Demographic pressure affects emissions gradually
Energy access variables	—	Omitted due to multicollinearity

Appendix C: Bhutan

Table 06. Short-Run ARDL Results for Bhutan

Variables	Coefficient Sign	Significance
CO_2 emissions (t−1)	Positive	**Significant (5%)**
GDP per capita (t)	Positive	**Significant (1%)**
GDP per capita (t−1)	Negative	**Significant (5%)**
GDP per capita (t−2)	Positive	**Significant (5%)**
Population (t)	Negative	**Significant (1%)**
Constant	Positive	**Significant (5%)**

Table 07. Summary of Short-Run Effects on CO_2 Emissions in Bhutan

Variables	Short-Run Effect	Interpretation
Lagged CO_2 emissions	Positive	Emissions exhibit strong persistence
GDP per capita	Mixed (dynamic)	Growth raises emissions with short-run adjustment
Population	Negative	Demographic scale effect is environmentally benign in the short run
Energy variables	—	Omitted due to multicollinearity and data constraints

Appendix D: India

Table 08. Short-Run ARDL Results for India

Variables	Coefficient Sign	Significance
CO_2 emissions (t−2)	Positive	**Significant (1%)**
GDP per capita (t)	Positive	**Significant (1%)**
Population (t)	Negative	Marginally insignificant
Population (t−1)	Positive	**Significant (5%)**
Population (t−2)	Negative	**Significant (1%)**
Renewable energy	Negative	**Significant (1%)**
Fossil fuel use	Positive	**Significant (5%)**
Electricity access	Negative	Insignificant
Constant	Positive	**Significant (1%)**

Table 09. Summary of Short-Run Effects on CO_2 Emissions in India

Variables	Effect on CO_2	Interpretation
GDP per capita	Positive	Growth-driven emission pressure
Population	Mixed	Short-run demographic adjustments
Renewable energy	Negative	Emission-mitigating role
Fossil fuels	Positive	Emission-intensive energy source
Electricity access	Neutral	Limited short-run impact

Appendix E: Maldives

Table 10. Short-Run ARDL Results for Maldives

Variables	Coefficient Sign	Significance
CO_2 emissions (t−1)	Positive	**Significant (1%)**
Population (t)	Positive	Marginally insignificant
GDP per capita (t)	Positive	Insignificant
GDP per capita (t−1)	Negative	**Significant (5%)**
Renewable energy	Negative	Marginally significant
Constant	Positive	Insignificant

Table 11. Summary of Short-Run Effects on CO_2 Emissions in Maldives

Variables	Short-Run Effect	Interpretation
Lagged CO_2 emissions	Strong positive	Emission persistence
Population	Weak positive	Limited short-run scale effect
GDP per capita	Delayed negative	Short-run efficiency adjustment

Renewable energy	Negative	Emission-mitigating role
Energy access variables	—	Dropped due to instability

Appendix F: Myanmar

Table 12. Short-Run ARDL Results for Myanmar

Variables	Coefficient Sign	Significance
CO_2 emissions (t−1)	Positive	**Significant (1%)**
CO_2 emissions (t−2)	Positive	Insignificant
GDP per capita (t)	Negative	Insignificant
GDP per capita (t−1)	Positive	**Significant (5%)**
Population (t)	Negative	Insignificant
Population (t−1)	Positive	Marginally insignificant
Population (t−2)	Negative	Marginally significant
Renewable energy (t)	Negative	**Significant (1%)**
Renewable energy (t−1)	Positive	**Significant (5%)**
Fossil fuels (t−1)	Negative	**Significant (1%)**
Fossil fuels (t−2)	Positive	**Significant (1%)**
Electricity access	Negative	Insignificant

Table 13. Summary of Short-Run Effects on CO_2 Emissions in Myanmar

Factors	Short-Run Impact	Interpretation
Emission persistence	Strong positive	Inertia in energy and production systems
Economic growth	Delayed positive	Growth-driven emissions with lag
Population	Mixed	Weak and non-linear scale effects
Renewable energy	Net negative	Emission-mitigating with adjustment
Fossil fuels	Volatile	Short-run energy substitution dynamics
Electricity access	Neutral	Limited direct short-run impact

Appendix G: Nepal

Table 14. Short-Run ARDL Results for Nepal

Variables	Direction of Effect	Significance
CO_2 emissions (t−1)	Negative	Insignificant
CO_2 emissions (t−2)	Positive	**Significant (5%)**
Population (t)	Negative	**Significant (1%)**
Population (t−1)	Positive	**Significant (1%)**
Population (t−2)	Negative	**Significant (1%)**
GDP per capita (t)	Positive	Marginal
Renewable energy (t)	Negative	**Significant (1%)**
Fossil fuels (t)	Negative	**Significant (1%)**
Fossil fuels (t−1)	Negative	**Significant (1%)**
Electricity access	Positive	Insignificant

Table 15. Summary of Short-Run Drivers of CO_2 Emissions in Nepal

Factors	Short-Run Impact
Emission persistence	Moderate
Population dynamics	Strong and mixed
Economic growth	Weak positive
Renewable energy	Emission-reducing
Fossil fuel use	Emission-increasing
Electricity access	Neutral

Appendix H: Pakistan

Table 16. Short-Run ARDL Results for Pakistan

Variables	Direction	Significance
CO_2 emissions (t−1)	Positive	Insignificant
CO_2 emissions (t−2)	Negative	**Significant (1%)**
GDP per capita (t)	Positive	**Significant (5%)**
GDP per capita (t−2)	Positive	**Significant (1%)**
Renewable energy (t)	Negative	**Significant (1%)**
Renewable energy (t−1)	Positive	Marginal
Fossil fuels (t−1)	Negative	**Significant (5%)**
Fossil fuels (t−2)	Positive	**Significant (1%)**
Electricity access	Negative	Insignificant

Table 17. Summary of Short-Run Drivers of CO_2 Emissions in Pakistan

Factors	Short-Run Impact
Emission persistence	Moderate
Economic growth	Strong positive
Renewable energy	Emission-reducing
Fossil fuel use	Volatile but emission-intensive
Electricity access	Neutral

Appendix I: Sri Lanka

Table 18. Short-Run ARDL Results for Sri Lanka

Variables	Direction of Effect	Significance
CO_2 emissions (t−2)	Negative	**Significant (5%)**
GDP per capita (t)	Negative	**Significant (1%)**
Population (t)	Positive	**Significant (1%)**
Renewable energy (t)	Negative	**Significant (1%)**
Renewable energy (t−2)	Negative	**Significant (1%)**
Fossil fuels (t−2)	Positive	**Significant (1%)**
Electricity access	Positive	Insignificant

Table 19. Summary of Short-Run Drivers of CO_2 Emissions in Sri Lanka

Factors	Short-Run Impact
Emission persistence	Moderate adjustment
Economic growth	Emission-reducing
Population growth	Emission-increasing
Renewable energy	Strong mitigation
Fossil fuel use	Delayed emission increase
Electricity access	Neutral