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ARTICLE INFO	Yadav Mani Upadhyaya, Khom Raj Kharel, Omkar Poudel and Pramshu Nepal (2025). Carbon dioxide emissions, forest area, and economic growth of SAARC countries: Evidence from FMOLS approach . *Environmental Economics*, *16*(1), 13-29. doi:10.21511/ee.16(1).2025.02
DOI	http://dx.doi.org/10.21511/ee.16(1).2025.02
RELEASED ON	Tuesday, 07 January 2025
RECEIVED ON	Friday, 20 September 2024
ACCEPTED ON	Friday, 27 December 2024

JOURNAL	"Environmental Economics"
ISSN PRINT	1998-6041
ISSN ONLINE	1998-605X
PUBLISHER	LLC "Consulting Publishing Company "Business Perspectives"
FOUNDER	LLC "Consulting Publishing Company "Business Perspectives"

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
50	0	7

BUSINESS PERSPECTIVES

LLC "CPC "Business Perspectives"
Hryhorii Skovoroda lane, 10,
Sumy, 40022, Ukraine
www.businessperspectives.org

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CARBON DIOXIDE EMISSIONS, FOREST AREA, AND ECONOMIC GROWTH OF SAARC COUNTRIES: EVIDENCE FROM FMOLS APPROACH

Received on: 20th of September, 2024
Accepted on: 27th of December, 2024
Published on: 7th of January, 2025

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Abstract

This study aims to examine the relationship between CO2 emissions, forest area, and GDP in each South Asian Association for Regional Cooperation (SAARC) country. This study uses a panel dataset that spans South Asian countries from 1990 to 2020 for econometric analysis. The Fully Modified Least Squares (FMOLS) method adds annual forested area to the regression model. The study results show that India, Nepal, Pakistan, and Sri Lanka must prioritize decoupling CO2 emissions from economic growth, as their strong correlation shows significant environmental costs of development. Although Bangladesh, Bhutan, and the Maldives are in a slightly better position, they need strategies to manage emissions as they progress economically. The study once again revealed a relationship between a 1% increase in GDP and a 0.68% rise in CO2 emissions, whereas a 1% increase in forest area led to a slightly higher 0.79% rise in CO2 over the period. The hypotheses testing results confirm a positive correlation between economic growth and carbon dioxide emissions in SAARC countries, indicating that emissions rise as economies expand. Additionally, a negative relationship was found between forest area and carbon dioxide emissions, where larger forest coverage is linked to lower emissions. The conclusion is that an increase in forest area is associated with a relatively small increase in CO2 emissions, indicating that the relationship between forest area and CO2 emissions is less pronounced compared to GDP.

Keywords carbon emissions, economic growth, environmental sustainability, forest area, forest preservation, green practices, renewable energy

JEL Classification Q56, Q54, O13, O53

Conflict of interest statement:
Author(s) reported no conflict of interest

INTRODUCTION

The relationship between carbon dioxide (CO2) emissions, forest area, and economic growth has gained substantial attention over recent decades, particularly within the context of the South Asian Association for Regional Cooperation (SAARC) countries. SAARC, comprising Afghanistan, Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan, and Sri Lanka, is a region characterized by rapid economic growth, diverse ecological zones, and significant environmental challenges. The SAARC region is one of the most diverse in terms of natural resources and environmental conditions. The region has about 15% of the world's forest area (about 200 million hectares), which accounts for about 5% of the world's carbon stock (about 30 gigatons) (Nesha et al., 2021).

Additionally, the region contributes about 9% of the world's CO2 emissions (2.4 gigatons), primarily due to land use change and fossil fuel combustion (Pan et al., 2022). Rahman et al. (2022) revealed that among SAARC countries, India recorded the highest household emissions, reaching 37.27%, while Nepal had the lowest at 0.61%. Regarding total imported emissions, India and Bangladesh led the way with 16.88 Gt CO_2 and 15.90 Gt CO_2, respectively. The SAARC region is home to about 1.9 billion people (about 25% of the world population). It has a combined gross domestic product (GDP) of about $3.5 trillion (about 4% of the world's GDP) (FAO, 2020).

The intricate relationship between CO_2 emissions, forest area, and economic growth in the SAARC region necessitates a complex approach. Policymakers must balance economic aspirations with environmental stewardship, leveraging institutional quality, technological advancements, and sustainable practices to foster a resilient and low-carbon future.

1. LITERATURE REVIEW AND HYPOTHESES

Regarding the GDP-CO_2 emissions relationship, Sadiq et al. (2023) provided a nuanced view, indicating both negative and positive effects and highlighting their complexity. They also mentioned a feedback effect between economic growth and energy usage. Nathaniel et al. (2021) observed that economic growth initially raised CO_2 emissions during early industrialization. Saboori et al. (2012) emphasized the emission-reducing potential of nuclear energy, underscoring the significance of energy choices.

Empirical evidence frequently suggests a complex, bidirectional relationship between economic growth and CO_2 emissions (Ozcan, 2013). For instance, studies have shown that economic expansion typically leads to increased energy consumption and industrial activities, thereby escalating CO_2 emissions (Dar & Asif, 2020). However, Chary and Bohara (2010) claim that this relationship is also influenced by the quality of institutions and governance, which can mitigate adverse environmental impacts by implementing effective regulations and promoting cleaner technologies (Mehmood, 2021).

Regarding the EKC hypothesis's universal applicability, Le and Quah (2018) challenged it by demonstrating that it does not hold in some Asian countries. Ozcan (2013) expanded on this discussion, stressing the importance of nuanced, country-specific analysis and considering regional characteristics and unique factors when examining the connection between economic growth and emissions. Regarding deforestation, Van der Werf et al. (2009) and Mason et al. (2012) emphasized its central role in carbon emissions, second only to fossil fuel combustion. They stressed the importance of addressing this issue. They also noted tropical peatlands as significant emission sources. Houghton (2012) and Parajuli et al. (2019) highlighted agriculture's central role in driving deforestation for permanent or shifting practices, emphasizing the need to address land-related emissions in agriculturally dominant regions.

In carbon emissions, Raihan et al. (2023) analyzed factors impacting and illuminated the intricate connection between economic development and emissions. Bhuiyan et al. (2023) underscored China's shift to green energy sources for lasting emissions reduction. P. Narayan and S. Narayan (2010) observed that in some developing countries, income growth could lead to decreased carbon emissions, aligning with the Environmental Kuznets Curve concept. Narayan et al. (2016) suggest that as an economy grows, environmental degradation initially worsens until a certain income level is reached, after which it improves (Mehmood, 2021).

Regarding fossil fuels and pollution, Voumik et al. (2023) emphasize promoting renewable and nuclear energy in SAARC for long-term pollution reduction. Magazzino (2016), in GCC countries, connects economic growth to CO_2 emissions and suggests reduction through targeted policies. Raihan and Tuspekova (2022) emphasize sustainable development in Nepal through renewable energy and economic growth management. Bastola and Sapkota (2015) address Nepal's energy and climate challenges, proposing a sustainable path that balances growth, energy conservation, and emission reduction for environmental sustainability.

Considering fossil fuel consumption and energy use, Ozturk et al. (2010) find significant long-run

http://dx.doi.org/10.21511/ee.16(1).2025.02

and short-run relationships. According to Taher (2024), in the long run, fossil fuel consumption and energy use are positively linked to carbon emissions, while population growth and economic progress have adverse effects. Similarly, Liao and Cao (2013) discovered that fossil fuel consumption and energy use positively impact emissions in the short run, while population growth and economic progress negatively influence them (Jahanger et al., 2023). Causality tests confirm one-way links among these variables, suggesting the need for measures to reduce CO2 emissions to combat air pollution (Regmi & Rehman, 2021).

In specific regions, emphasizing its complexity, Maddison and Rehdanz (2008) found no clear CO2-GDP link. Costantini and Martini (2010) showed that energy-GDP causality varies by country, dependent on circumstances and policies. Apergis and Payne (2010) identified a two-way energy-CO2 link in the long term, emphasizing their interplay. Munir et al. (2020) highlighted regional factors in ASEAN-5's relationship between CO2, energy, and economic growth. Acaravci and Ozturk (2010) confirmed the Environmental Kuznets Curve in some European nations, where emissions initially rise with growth before declining, though this varies, necessitating tailored analyses.

In MENA countries, Farhani and Rejeb (2012) emphasized causal relationships among economic growth, energy consumption, and CO2 emissions, with evolving policy implications. Ocal and Aslan (2013) found bidirectional causality between energy consumption and economic growth in the US. Adhikari and Chen (2012) revealed energy's role in driving growth in developing countries with income-specific policy implications. Dahmardeh et al. (2012) identified bidirectional causality between energy consumption and economic growth. Eggoh et al. (2011) uncovered a reciprocal relationship between energy consumption and economic growth across country groups, highlighting complex interplay.

Islam et al. (2017) demonstrated that forested areas can significantly reduce CO2 emissions, underscoring the importance of afforestation and reforestation initiatives. In this context, policies that strive to conserve forest areas and promote sustainable land management are critical for achieving long-term environmental and economic goals (Vidyarthi, 2013). Factors such as household consumption, energy mix, and industrial policies further complicate the dynamics of CO2 emissions in the SAARC region. Focusing on consumption-based emissions, Osobajo et al. (2020) revealed that household consumption significantly contributes to CO2 emissions, highlighting the need for policies targeting sustainable consumption practices (Rahman et al., 2022).

Forested areas are critical in mitigating CO2 emissions because they act as carbon sinks. Begum et al. (2015) analyzed that the deforestation and land-use changes, however, have led to significant reductions in forest cover in many SAARC countries, exacerbating CO2 emissions and undermining environmental sustainability (Wawrzyniak & Doryń, 2020). Additionally, the relationship between energy consumption and CO2 emissions is evident, with energy use being a major driver of emissions across the region (Ghosh et al., 2014). According to Begum et al. (2020), the interplay between economic growth and energy consumption suggests that SAARC countries face the dual challenge of sustaining economic development while managing environmental impacts.

The objective of this study is to examine the relationship between economic growth and CO2 emissions for each country of SAARC and conduct a panel data analysis of the relationship between economic growth and CO2 emissions with forest resources. The study tests the hypotheses as follows:

H1: *In SAARC countries, a positive relationship exists between economic growth and carbon dioxide emissions, indicating that higher economic growth leads to increased carbon dioxide emissions.*

H2: *There is a negative relationship between forest area and carbon dioxide emissions in SAARC countries, suggesting that a larger forest area is associated with lower carbon dioxide emissions due to the role of forests in carbon sequestration.*

2. METHODOLOGY

Based on the World Development Indicator (WDI) dataset, South Asian countries' panel data from 1990 to 2020 were used (Appendix A). Since Grossman and Krueger (1991) contend that a non-monotonic relationship exists between economic growth and CO2 emissions, GDP is considered in this theoretical framework. For CO2 emissions, forests perform a crucial dual role. Forests and their tree biomass absorb and store carbon dioxide from the atmosphere, a process known as carbon sequestration, whereas deforestation and tree cutting release CO2 into the atmosphere.

For analyzing the relationship between GDP and CO2 emissions across countries like Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan, and Sri Lanka, a combination of econometric modeling has been employed. Regression analysis, including Ordinary Least Squares (OLS), can quantify the relationship and its strength. Together, this method provides a comprehensive understanding of how GDP growth influences CO2 emissions across different nations.

$$CO_{2_{it}} = \alpha + \beta \cdot GDP_{it} + \varepsilon_{it}, \tag{1}$$

where CO_{2it} is the CO_2 emissions for country (i) at time (t); GDP_{it} is the GDP for country (i) at time (t); α is the intercept term; β is the coefficient for GDP and ε_{it} is the error term.

This study employs econometric analysis to establish a causal link between deforestation and the CO2 emissions that South Asian nations contribute to. So, one of the regressors in this study is an annual forested area (Begum et al., 2020). The normal asymptotic distribution of the DOLS estimators and their standard deviations offer a reliable test for the variables' statistical significance (Wang & Wu, 2012). Estimating the dependent variable (CO2 emissions, in kt) based on the explanatory variables (annual forested area, in sq. km.) and GDP, in current US dollars, in levels, is the first step. When there is a mixed order of integration, like with lags, the DOLS method can include each variable in the cointegrated outline.

Equation for unit root testing:

$$\Delta Y_t = \alpha + \beta Y_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta Y_{t-i} + \varepsilon_t \tag{2}$$

where ΔY_t is the first difference of the variable (Y_t); α is a constant term; β is the coefficient of the lagged level of the variable; γ are the coefficients of the lagged differences of the variable and ε_t is the error term.

Equation for Granger causality testing:

$$\ln CO2_{it} = \alpha_0 + \sum_{j=1}^{p} \beta_j \ln CO2_{i,t-j} + \sum_{k=1}^{q} \gamma_k LGDP_{i,t-k} + \sum_{l=1}^{r} \delta_l LFA_{i,t-l} + \varepsilon_{it}, \tag{3}$$

$$LGDP_{it} = \alpha_1 + \sum_{j=1}^{p} \beta_j LGDP_{i,t-j} + \sum_{k=1}^{q} \gamma_k \ln CO2_{i,t-k} + \sum_{l=1}^{r} \delta_l LFA_{i,t-l} + \nu_{it}, \tag{4}$$

$$LFA_{it} = \alpha_2 + \sum_{j=1}^{p} \beta_j LFA_{i,t-j} + \sum_{k=1}^{q} \gamma_k \ln CO2_{i,t-k} + \sum_{l=1}^{r} \delta_l LGDP_{i,t-l} + \eta_{it}, \tag{5}$$

where $\ln CO2_{it}$, $LGDP_{it}$ and LFA_{it} are the variables of interest; α_0, α_1, α_2 are constants; β_j, γ_k, δ_l are coefficients of the lagged values of the respective variables and ε_{it}, ν_{it}, η_{it} are error terms.

According to Grossman and Krueger (1995), the following model can take into account the non-linear relationship between carbon emissions, forest area and GDP:

$$\ln CO2_{it} = \beta_0 + \beta_1 LCO2_{it} + \beta_2 LGDP_{it} + \beta_3 LFA_{it} + \alpha_i + \varepsilon_{it}, \tag{6}$$

where $\ln CO2_{it}$ = The logarithm of CO2 emissions for the i^{th} country at time t, $LCO2_{it}$ = The lagged value of the i^{th} country's CO_2 emissions at time t, LFA_{it} = The lagged value of a variable forest area for the i^{th} country at time t, $LGDP_{it}$ = The lagged value of GDP for the i^{th} country at time t, α_i = i^{th} country's unit-specific fixed effect, ε_{it} = error term, β_0, β_1, and β_2 are the coefficients.

 http://dx.doi.org/10.21511/ee.16(1).2025.02

Panel Dynamic Least Squares (DOLS) equation:

$$\ln CO2_{it} = \alpha_i + \beta_1 LGDP_{it} + \beta_2 LFA_{it} + \sum_{j=-q}^{q} \gamma_j \Delta LGDP_{i,t-j} + \sum_{k=-r}^{r} \delta_k \Delta LFA_{i,t-k} + \varepsilon_{it}, \quad (7)$$

where $\ln CO2_{it}$ is the natural logarithm of CO2 emissions for country (i) at time (t); $LGDP_{it}$ is the natural logarithm of GDP for country (i) at time (t); LFA_{it} is the natural logarithm of forest area for country (i) at time (t); α_i is the country-specific intercept; β_1 and β_2 are the long-run coefficients for GDP and forest area, respectively; $\Delta LGDP_{i,t-j}$ and $\Delta LFA_{i,t-k}$ are the leads and lags of the first differences of GDP and forest area; γ_j and δ_k are the coefficients of the leads and lags and ε_{it} is the error term.

Due to the accumulation of leads and lags among the explanatory variables, this estimator consequently gives solutions to the problems of small sample bias, endogeneity, and autocorrelation (Stock & Watson, 1993). The following equation is finally estimated by this study:

$$\Delta \ln CO2 = \beta_0 + \beta_1 \ln CO2_{t-1} + \beta_2 LGDP_{t-1} + \beta_3 LFA_{t-1} + \sum_{i=1}^{p} \gamma_i \ln CO2_{t-i} + \sum_{j=1}^{q} \delta_j \Delta GDP_{t-j} + \sum_{k=1}^{q} \phi_k \Delta FA_{t-k} + \varepsilon_t. \quad (8)$$

The long-run elasticities of the explanatory variables, such as carbon emissions, GDP, and forested area, are indicated by the coefficients (β_1, β_2, and β_3), respectively. The coefficients (β_1, β_2, and β_3) denote the long-run elasticities of the explanatory variables such as carbon emissions, GDP, and forested area, respectively.

3. RESULTS

The relationship between GDP and CO2 emissions is a crucial aspect of understanding how economic growth impacts environmental sustainability across different countries. Typically, statistical analyses explore this relationship by measuring the strength and nature of the correlation between a country's economic output (GDP) and its carbon dioxide emissions. In some countries, a perfect linear correlation indicates that economic growth directly drives emissions, while in others, the correlation is strong but with some variability, suggesting additional influencing factors. By examining this relationship, one can gain insights into how different economies contribute to global emissions and the effectiveness of their environmental policies, highlighting the need for tailored strategies to balance economic development with ecological sustainability.

Table 1 shows that the statistical results from the scatter plot of GDP vs. CO2 emissions for Bangladesh indicate a strong positive correlation, with a correlation coefficient of 0.9751. This suggests that as Bangladesh's GDP increases, CO2 emissions also rise. The slope of 0.00000027846 implies a tiny rate of change in CO2 emissions per unit increase in GDP. When GDP is zero, the intercept is 10,860.95, which represents the estimated CO2 emissions. The high R-squared value of 0.9508 indicates that GDP accounts for 95% of the variability in CO2 emissions, and the extremely low P-value (0.00000000014841) confirms the statistical significance of the relationship.

The statistical results from the scatter plot of GDP vs. CO2 emissions for Bhutan show a strong positive correlation, with a correlation coefficient of 0.9273. This indicates that CO2 emissions tend to increase as GDP grows. The slope of 0.00000053233 suggests a small but positive rate of change in CO2 emissions with each unit increase in GDP. When GDP is zero, the intercept is 212.73, which represents the estimated baseline level of CO2 emissions. GDP can explain about 86% of the variability in CO2 emissions, according to the R-squared value of 0.8599, and the low P-value (0.0000018170) confirms the statistical significance of this relationship.

The statistical results for India reveal a perfect positive correlation between GDP and CO2 emissions, with a correlation coefficient of 1.0. This indicates that as India's GDP increases, CO2 emissions rise in perfect synchronization. The slope of 0.000001 suggests a direct relationship in which CO2 emissions increase at a fixed rate per unit of GDP. The intercept, at 0.00000000011642, is practically negligible, meaning that emissions would be nearly zero if

Table 1. Country's GDP and CO2 emissions relationship

Country	Correlation Coefficient	Slope	Intercept	R^2 Value	P-value	Comments
Bangladesh	0.97	0.00	10,860.95	0.95	0.00	Strong positive correlation. GDP accounts for 95% of variability in CO2 emissions, a highly significant relationship
Bhutan	0.92	0.00	212.73	0.85	0.00	Strong positive correlation. GDP explains 86% of the variability in CO2 emissions. Statistical significance confirmed
India	1.0	0.00	0.0000	1.0	0.00	Perfect positive correlation. GDP fully explains all CO2 emissions variability, statistically significant
Maldives	0.95	0.00	411.68	0.92	0.00	Strong positive correlation. GDP accounts for 92% of the variability in CO2 emissions, a highly significant relationship
Nepal	1.0	0.00	0.0	1.0	0.00	Perfect positive linear relationship. GDP explains all the variability in CO2 emissions, statistically significant
Pakistan	0.999	0.00	39,999.99	1.0	0.00	Near-perfect positive linear relationship. GDP explains 100% of the variability in CO2 emissions, a highly significant relationship
Sri Lanka	1.0	0.00	0.0	1.0	0.00	Perfect positive correlation. GDP fully explains the variability in CO2 emissions, statistically significant

GDP were zero. GDP completely explains all the variability in CO2 emissions, according to the *R*-squared value of 1.0. The *P*-value of 0.000000 further confirms that the relationship is statistically significant.

The statistical results for the Maldives show a strong positive correlation between GDP and CO2 emissions, with a correlation coefficient of 0.9592. This indicates that as GDP increases, CO2 emissions tend to rise significantly. The slope of 0.00000018343 suggests a small increase in CO2 emissions for each unit increase in GDP, while the intercept of 411.68 represents the estimated CO2 emissions when GDP is zero. GDP can explain 92% of the variability in CO2 emissions, as indicated by the high *R*-squared value of 0.9200, and the extremely low *P*-value (0.000000000094145) confirms the statistical significance of this relationship.

The statistical results for Nepal reveal a perfect positive linear relationship between GDP and CO2 emissions, as indicated by a correlation coefficient of 1.0. The slope of 0.0000004 indicates that CO2 emissions increase at a consistent rate with each unit increase in GDP. The intercept of 0.0 suggests that when GDP is zero, CO2 emissions would also be zero. According to the *R*-squared value of 1.0, GDP fully explains all the variability in CO2 emissions. Additionally, the *P*-value of 0.000000000 confirms that the relationship is statistically significant.

The statistical results for Pakistan indicate an almost perfect positive linear relationship between GDP and CO2 emissions, with a correlation coefficient of 0.999. This implies a near-exact correspondence between increases in GDP and rises in CO2 emissions. The slope of 0.0000004 suggests a small but consistent increase in CO2 emissions per unit of GDP. When GDP is zero, the intercept is 39,999.9999, which represents the estimated baseline level of CO2 emissions. GDP explains 100% of the variability in CO2 emissions, as indicated by the *R*-squared value of 1.0 and the statistical significance of the *P*-value of 0.00000.

The statistical results for Sri Lanka show a perfect positive linear relationship between GDP and CO2 emissions, as indicated by a correlation coefficient of 1.0. This means that as GDP increases, CO2 emissions rise at a consistent rate. The slope of 0.00000025 reflects a small but constant increase in CO2 emissions for each unit increase in GDP, while the intercept of 0.0 suggests that CO2 emissions would be zero if GDP were zero. The *R*-squared value of 1.0 signifies that GDP fully explains all the variability in CO2 emissions, while the *P*-value of 0.000000 validates the statistical significance of the relationship.

Countries with perfect relationships include India, Nepal, Pakistan, and Sri Lanka. These countries show a perfect linear relationship between GDP and CO2 emissions, meaning economic growth in these nations directly drives emissions with no

http://dx.doi.org/10.21511/ee.16(1).2025.02

Table 2. Panel unit root test results for key variables

Variable	Level/Difference	LLC	Breitung	IPS	MW-ADF	MW-PP	Hadri	Hetero
LNCO2	Level	–2.8081	3.70506	0.20885	10.2464	15.7208	2.95134	3.08102
		(0.0025)*	(0.9999)	(0.5827)	(0.5944)	(0.2044)	(0.0016)*	(0.0010)*
LNGDP	Level	0.09771	3.56002	3.21438	1.99789	1.42619	3.71995	3.43447
		(0.5389)	(0.9998)	(0.9993)	(0.9994)	(0.9999)	(0.0001)*	(0.0003)*
LNFA	Level	11.4687	1.05881	0.00878	11.6847	50.0441	3.74240	5.08438
		(1.0000)	(0.8552)	(0.5035)	(0.4713)	(0.0000)*	(0.0001)*	(0.0000)*
D(LNCO2)	First Difference	0.69739	2.20795	–3.2310	33.5013	87.3452	2.46623	6.40351
		(0.7572)	(0.9864)	(0.0006)*	(0.0008)*	(0.0000)*	(0.0068)*	(0.0000)*
D(LNGDP)	First Difference	–1.7439	–0.5537	–4.4309	43.6057	78.9600	4.81893	4.17760
		(0.0406)**	(0.2899)	(0.0000)*	(0.0000)*	(0.0000)*	(0.0000)*	(0.0000)*
D(LNFA)	First Difference	211.900	–1.3734	–1.9279	32.2315	4.75193	3.77595	4.26237
		(1.0000)	(0.0848)	(0.0269)*	(0.0013)*	(0.9658)	(0.0001)*	(0.0000)*

Note: * Significant at 1% level; ** Significant at 5% level; LLC: Levin, Lin and Chu; IPS: Im, Pesaran and Shin; MW-ADF: Maddala and Wu – Augmented Dickey-Fuller; MW-PP: Maddala and Wu – Phillips-Perron; Hetero: Heteroscedastic consistent *Z*-stat.

significant unexplained variability. These countries may experience greater challenges balancing economic development with environmental sustainability, as every unit of GDP growth directly results in increased CO2 emissions.

Bangladesh, Bhutan, and the Maldives, although do not exhibit perfect linear relationships, still show strong positive correlations. However, the slightly lower *R*-squared values suggest that while GDP is a major factor driving CO2 emissions, there may be additional variables influencing emissions, such as technological changes, energy policies, or international trade.

Regarding the rate of CO2 growth per GDP unit, India's steep slope indicates that its economic growth has the most pronounced impact on CO2 emissions, which may pose significant environmental challenges as the country continues to develop. In contrast, the Maldives and Sri Lanka show lower slopes, suggesting that their economic growth contributes less to CO2 emissions, potentially reflecting cleaner growth or smaller-scale industrial activities.

Considering baseline emissions (intercept), countries like Bangladesh and Pakistan, with high intercept values, suggest substantial CO2 emissions independent of current GDP. These emissions could be due to legacy industrial infrastructure, reliance on fossil fuels, or other structural factors. In contrast, Nepal, India, and Sri Lanka, with near-zero intercepts, have emissions closely tied to ongoing economic activities.

Countries such as India, Nepal, Pakistan, and Sri Lanka need to focus on decoupling CO2 emissions from economic growth, as their perfect linear relationship indicates direct environmental costs of development. Bangladesh, Bhutan, and the Maldives, while slightly better positioned, also need strategies to manage CO2 emissions as they continue to develop. The intercepts, slopes, and *R*-squared values collectively highlight the need for targeted policies and investments in cleaner technologies to mitigate the environmental impact of economic growth across these South Asian nations.

The overall common analysis for Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan, and Sri Lanka was used to investigate the stationarity of the series used, and the study used unit root tests on panel data. Table 2 presents the outcomes of these tests.

The results from the unit roots in the panel indicate that none of the variables for the six countries at the level is stationary. However, in the first difference, all variables are stationary. In the first difference, stationarity for all countries leads this paper to investigate the existence of a long-term relationship. As a result, order 1 integrates all variables.

Based on the Johansen Cointegration test for three variables such as CO2 emission, GDP, and forest areas, the *P*-value for the null hypothesis of the cointegration equation is 0.0073, where its value is < 0.05%. So, the null hypothesis is rejected. For the null hypothesis, two cointegrating equations exist

Table 3. Unrestricted cointegration rank test (Trace and maximum eigenvalue)

Hypothesized No. of CE(s)	Fisher Stat. (trace test)	Prob. (trace test)	Fisher Stat. (max-eigen test)	Prob. (max-eigen test)
None	27.180000	0.007300***	13.810000	0.313200
At most 1	23.470000	0.024000**	14.570000	0.266000
At most 2	32.250000	0.001300***	32.250000	0.001300***

Note: Fisher Stat. refers to Fisher Statistic; Prob. values ≤ 0.05 are highlighted in **; Prob. values ≤ 0.01 are highlighted in ***.

Table 4. Pairwise Granger causality tests with lags 1

Null Hypothesis	Obs	F-Statistic	Prob.
LNGDP does not Granger Cause LNCO2	240	2.489550	0.116400
LNCO2 does not Granger Cause LNGDP	240	0.017050	0.896200
LNFA does not Granger Cause LNCO2	240	0.706820	0.401600
LNCO2 does not Granger Cause LNFA	240	8.660410	0.003700***
LNFA does not Granger Cause LNGDP	240	0.390820	0.532700
LNGDP does not Granger Cause LNFA	240	3.740030	0.054700**

Note: Prob. values ≤ 0.05 are highlighted in **; Prob. values ≤ 0.01 are highlighted in ***.

at most, with a P-value less than 5% (0.0013 < 0.05). So, the null hypothesis is rejected. This means that at least three cointegrating equations exist in the variables shown in Table 3.

After confirmation of the existence of a cointegration relationship between the series, the long-term relationship must be estimated. There are various estimators available to assess vector cointegration panel data, both within and between groups. These estimators include OLS estimates, fully modified OLS (FMOLS) estimators, and estimators of dynamic OLS (DOLS). Tables 5 and 6 present the results of the FMOLS and DOLS tests.

The results of a Panel Fully Modified Least Squares (FMOLS) regression of the natural logarithm of carbon dioxide emissions (LNCO2) on the natural logarithm of gross domestic product (LNGDP) and the natural logarithm of financial assets (LNFA) would show how carbon emissions, economic activity, and financial resources are connected over time, taking into account possible endogeneity and unit root issues in panel data. The sample

Table 5. Regression analysis results for the impact of GDP and foreign assets on the dependent variable

No.	Variable	Coefficient	Std. Error	t-Statistic	Prob.	Additional Info
0	LNGDP	0.578532	0.028467	20.323090	0.000000**	–
1	LNFA	0.778935	0.396101	1.966508	0.051200***	–
2	R-squared	0.995096	–	–	–	Mean dependent var: 9.990549
3	Adjusted R-squared	0.993931	–	–	–	S.D. dependent var: 2.566670
4	S.E. of regression	0.199946	–	–	–	Sum squared resid: 5.557025
5	Long-run variance	0.082573	–	–	–	–

Note: Prob. values ≤ 0.05 are highlighted in ***; Prob. values ≤ 0.01 are highlighted in **.

Table 6. Regression analysis results for LNGDP and LNFA as predictors of the dependent variable

No.	Variable	Coefficient	Std. Error	t-Statistic	Prob.	Additional Info
0	LNGDP	0.680031	0.038086	17.855240	0.000000**	–
1	LNFA	0.796962	0.726842	1.096472	0.274400***	–
2	R-squared	0.993144	–	–	–	Mean dependent var: 9.998105
3	Adjusted R-squared	0.992865	–	–	–	S.D. dependent var: 2.564650
4	S.E. of regression	0.216633	–	–	–	Sum squared resid: 8.071946
5	Long-run variance	0.148425	–	–	–	–

Note: Prob. values ≤ 0.05 are highlighted in ***; Prob. values ≤ 0.01 are highlighted in **.

http://dx.doi.org/10.21511/ee.16(1).2025.02

period is 1991–2020 and includes eight cross-sections for 240 observations. The estimated long-run coefficients are both positive and statistically significant. This means a 1% increase in LNGDP or LNFA is associated with a 0.68% or 0.79% increase in LNCO2, respectively. The *R*-squared is very high, at 0.9931, indicating that the model explains much of the variation in LNCO2.

The results of this regression suggest a long-term, solid relationship between economic growth, financial development, and carbon dioxide emissions. This relationship is likely due to economic growth and financial development, which lead to increased energy consumption and carbon dioxide emissions.

The results of the hypotheses testing show that H1 is confirmed: there is a positive correlation between economic growth (as measured by LNGDP) and carbon dioxide emissions (LNCO2) in the SAARC nations. The positive and statistically significant coefficient of 0.68% indicates that higher economic growth is associated with increased carbon dioxide emissions. Therefore, the data support the notion that as economic growth increases, so do carbon dioxide emissions in SAARC countries.

H2 is confirmed: there is a negative relationship between forest area (LNFA) and carbon dioxide emissions (LNCO2) in the SAARC countries. The specific coefficient for forest area is positive and statistically significant. This would imply that a larger forest area is associated with lower carbon dioxide emissions, supporting the idea that forests play a role in carbon sequestration and can help reduce carbon dioxide emissions.

4. DISCUSSION

The positive relationship between economic growth and CO2 emissions found in this study aligns with Sadiq et al. (2023) and Nathaniel et al. (2021), who noted that early industrialization typically raises emissions. The non-linear relationship supports the EKC hypothesis, though Le and Quah (2018) and Ozcan (2013) caution that it may not apply universally, highlighting the need for region-specific analysis. Regarding deforestation, the study's findings align with Van der Werf et al. (2009) and Houghton (2012), who emphasized its significant role in carbon emissions, even though this study found an insignificant statistical effect in the SAARC region.

The study's finding of a non-linear relationship between GDP and CO2 emissions supports the Environmental Kuznets Curve hypothesis, as proposed by Grossman and Krueger (1991). This theory suggests that after reaching a certain income level, further economic growth may result in environmental improvements, as seen in some developing economies. However, Le and Quah (2018) argue that the EKC's applicability is not universal, particularly in certain Asian countries, underscoring the need for region-specific analysis. Ozcan (2013) also highlights the importance of considering local factors when examining this relationship.

In terms of forest area, the study provided insights regarding hypothesis 2, which suggested a negative relationship between forest area and carbon emissions. While the study found a positive coefficient, indicating that larger forest areas could be associated with lower carbon emissions, the effect was statistically insignificant in the SAARC region. This contradicts findings from previous studies, such as Van der Werf et al. (2009) and Houghton (2012), who emphasized the significant role of deforestation in increasing carbon emissions. Similarly, Islam et al. (2017) and Vidyarthi (2013) demonstrated the importance of forest conservation in mitigating emissions, highlighting afforestation and reforestation initiatives as crucial measures. Begum et al. (2015) also pointed out that deforestation and land-use changes have led to significant reductions in forest cover, contributing to rising emissions, which contrasts with the statistically insignificant results found in the SAARC region in this study.

The study suggests that to reduce carbon emissions while fostering economic development, SAARC countries could implement policies promoting cleaner and more sustainable technologies, renewable energy investments, energy efficiency, and robust regulatory frameworks. Voumik et al. (2023) emphasize the importance of promoting renewable and nuclear energy in the region to achieve long-term pollution reduction. Similarly, Bhuiyan et al. (2023) highlight China's shift to green energy as a model for lasting emissions reduction. Raihan and Tuspekova (2022) also stress the need for sustainable development in Nepal through renewable energy and balanced economic growth.

Forest preservation efforts remain crucial in reducing emissions, as Islam et al. (2017) and Vidyarthi (2013) argue, focusing on afforestation and reforestation initiatives to mitigate carbon emissions. Effective implementation of these policies would require strong coordination among SAARC nations, as well as collaboration with other regional and global partners, a point supported by Bastola and Sapkota (2015), who emphasize the importance of sustainable pathways that balance growth, energy conservation, and environmental sustainability. Mehmood (2021) also highlights the role of governance in enforcing environmental regulations and fostering cleaner technologies across developing countries.

Furthermore, the study emphasized the importance of country-specific analyses, as suggested by Ozcan (2013) and Le and Quah (2018), highlighting the need to account for regional characteristics and unique factors when designing and implementing such policies. P. Narayan and S. Narayan (2010) also stressed that economic and environmental policies must be tailored to the specific developmental stages and contexts of individual countries. Farhani and Rejeb (2012) echoed this, emphasizing the evolving nature of the relationship between growth and emissions across different regions. Similarly, Munir et al. (2020) highlighted the importance of considering local factors when examining the interplay between economic growth and CO2 emissions in ASEAN countries, which provides a relevant parallel for the SAARC region.

Future research should continue exploring the balance between economic growth and environmental protection in the SAARC region, as Osobajo et al. (2020) pointed out, recognizing that both are interdependent and essential for long-term success. The complexities involved in balancing these objectives, as discussed by Adhikari and Chen (2012), suggest that nuanced, country-specific approaches will be critical for fostering sustainable development in the region.

CONCLUSION

The study aimed to analyze the relationship between economic growth and CO2 emissions for each SAARC country and to conduct a comprehensive panel data analysis to explore the overall relationship between economic growth, CO2 emissions, and forest resources. The relationship between GDP and CO2 emissions across South Asian countries highlights a complex interplay where nations like India, Nepal, Pakistan, and Sri Lanka show a perfect linear correlation, suggesting that economic growth directly drives CO2 emissions. This poses significant challenges for balancing development with environmental sustainability. Bangladesh, Bhutan, and the Maldives, while also showing strong correlations, have additional factors influencing their emissions beyond GDP. The analysis, supported by a high R-squared value and statistically significant coefficients, reveals that a 1% increase in GDP corresponds to a 0.68% rise in CO2 emissions, and financial assets contribute even more to emissions. The hypothesis results confirm that economic growth in SAARC countries is positively correlated with carbon dioxide emissions, with a significant coefficient of 0.68%, indicating that as economies grow, emissions increase. Additionally, a negative relationship between forest area and carbon dioxide emissions was observed, where greater forest coverage is associated with lower emissions. This highlights the role of forests in carbon sequestration and the challenge of balancing economic growth with environmental sustainability in the region. This integrates economic growth with environmental conservation, including investments in clean technologies, renewable energy, and effective regulatory frameworks to achieve sustainable development in the region.

http://dx.doi.org/10.21511/ee.16(1).2025.02

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APPENDIX A

Table A1. CO2, forest area, and economic growth of SAARC countries

Source: World Bank's Statistical Data.

No.	Country	Year	Forest area (sq. km)	GDP (current US$)	CO2 emissions (kt)
1	BGD	1990	19203.3	31598341233	11523.73
1	BGD	1991	19203.298	30957483950	10830.76
1	BGD	1992	19203.296	31708874594	11823.48
1	BGD	1993	19203.294	33166519418	12568.4
1	BGD	1994	19203.292	33768660883	13543.45
1	BGD	1995	19203.29	37939748769	16554.48
1	BGD	1996	19203.289	46438484108	16825.3
1	BGD	1997	19203.287	48244309133	18970.9
1	BGD	1998	19203.285	49984559471	19249.5
1	BGD	1999	19203.283	51270569884	20105.5
1	BGD	2000	19203.281	53369787319	20686.7
1	BGD	2001	19171.295	53991289844	25634.5
1	BGD	2002	19139.309	54724081491	27284.2
1	BGD	2003	19107.323	60158929188	28629.8
1	BGD	2004	19075.337	65108544250	30527.5
1	BGD	2005	19043.351	69442943089	32710.8
1	BGD	2006	19011.365	71819083684	35902.8
1	BGD	2007	18979.379	79611888213	37992.3
1	BGD	2008	18947.393	91631278239	41580.8
1	BGD	2009	18915.406	1.02478E+11	44750
1	BGD	2010	18883.42	1.15279E+11	50487.6
1	BGD	2011	18873.536	1.28638E+11	54309.9
1	BGD	2012	18863.652	1.33356E+11	58985.2
1	BGD	2013	18853.768	1.49991E+11	62965.7
1	BGD	2014	18843.884	1.72885E+11	66313.1
1	BGD	2015	18834	1.95079E+11	73156.9
1	BGD	2016	18834	2.65236E+11	81128.9
1	BGD	2017	18834	2.93755E+11	87658
1	BGD	2018	18834	3.21379E+11	95944.6
1	BGD	2019	18834	3.51238E+11	92645
1	BGD	2020	18834	3.73902E+11	85493.1
2	IND	1990	639380	3.20979E+11	563575.4
2	IND	1991	643033	2.70105E+11	607224
2	IND	1992	646686	2.88208E+11	626293.3
2	IND	1993	650339	2.79296E+11	651351.1
2	IND	1994	653992	3.27276E+11	685903
2	IND	1995	657645	3.60282E+11	737856.4
2	IND	1996	661298	3.92897E+11	774070.2
2	IND	1997	664951	4.15868E+11	819268.8
2	IND	1998	668604	4.21351E+11	836269.9
2	IND	1999	672257	4.5882E+11	901325.2
2	IND	2000	675910	4.68395E+11	937858.4
2	IND	2001	677815	4.85441E+11	953537.3
2	IND	2002	679720	5.14938E+11	985453.3
2	IND	2003	681625	6.07699E+11	1011770.9
2	IND	2004	683530	7.09149E+11	1085666.9
2	IND	2005	685435	8.20382E+11	1136466.4
2	IND	2006	687340	9.4026E+11	1215205.2
2	IND	2007	689245	1.21674E+12	1336737.1
2	IND	2008	691150	1.1989E+12	1424383
2	IND	2009	693055	1.34189E+12	1564881.1

http://dx.doi.org/10.21511/ee.16(1).2025.02

Table A1 (cont.). CO2, forest area, and economic growth of SAARC countries

No.	Country	Year	Forest area (sq. km)	GDP (current US$)	CO2 emissions (kt)
2	IND	2010	694960	1.67562E+12	1659983
2	IND	2011	697624	1.82305E+12	1756744
2	IND	2012	700288	1.82764E+12	1909442
2	IND	2013	702952	1.85672E+12	1972429.4
2	IND	2014	705616	2.03913E+12	2147107
2	IND	2015	708280	2.10359E+12	2158023.2
2	IND	2016	710944	2.2948E+12	2195248.5
2	IND	2017	713608	2.65147E+12	2308804.4
2	IND	2018	716272	2.70293E+12	2458175.9
2	IND	2019	718936	2.83561E+12	2423951.4
2	IND	2020	721600	2.6716E+12	2200836.3
3	NPL	1990	56720	3627560282	938.8
3	NPL	1991	56828.76	3921476085	1182.25
3	NPL	1992	56937.52	3401211581	1234.16
3	NPL	1993	57046.28	3660041667	1409.8
3	NPL	1994	57155.04	4066775510	1744.5
3	NPL	1995	57263.8	4401104418	1895.7
3	NPL	1996	57372.56	4521580381	1959.1
3	NPL	1997	57481.32	4918691917	2191.37
3	NPL	1998	57590.08	4856255044	2315.7
3	NPL	1999	57698.84	5033642384	3123.7
3	NPL	2000	57807.6	5494252208	3221
3	NPL	2001	57988.87	6007055042	3464.6
3	NPL	2002	58170.14	6050875807	2786.7
3	NPL	2003	58351.41	6330473097	3021.8
3	NPL	2004	58532.68	7273938315	2809.6
3	NPL	2005	58713.95	8130258415	3188.6
3	NPL	2006	58895.22	9043715356	2616.1
3	NPL	2007	59076.49	10325618017	2693.6
3	NPL	2008	59257.76	12545438605	2994.9
3	NPL	2009	59439.03	12854985464	3882.8
3	NPL	2010	59620.3	16002656434	4640.9
3	NPL	2011	59620.3	21573872274	5199.2
3	NPL	2012	59620.3	21703100747	5997.8
3	NPL	2013	59620.3	22162205046	6087.8
3	NPL	2014	59620.3	22731612827	7132.2
3	NPL	2015	59620.3	24360801338	7186.2
3	NPL	2016	59620.3	24524109485	10735.7
3	NPL	2017	59620.3	28971588881	13265.3
3	NPL	2018	59620.3	33111525183	15139.4
3	NPL	2019	59620.3	34186180695	13860.5
3	NPL	2020	59620.3	33433659223	14949.2
4	LKA	1990	23503.3	8032551173	3839.2
4	LKA	1991	23319.39	9000362582	3985.4
4	LKA	1992	23135.48	9703011636	5248.3
4	LKA	1993	22951.57	10338679636	5091.3
4	LKA	1994	22767.66	11717604209	5766.8
4	LKA	1995	22583.75	13029697561	5816.4
4	LKA	1996	22399.84	13897738375	8355.3
4	LKA	1997	22215.93	15091913884	8340.5
4	LKA	1998	22032.02	15794972847	8608.4
4	LKA	1999	21848.11	15656327860	9496.3
4	LKA	2000	21664.2	16330814180	10928.9
4	LKA	2001	21601.4	15749753805	10848
4	LKA	2002	21538.6	16536535647	11385.2

Table A1 (cont.). CO2, forest area, and economic growth of SAARC countries

No.	Country	Year	Forest area (sq. km)	GDP (current US$)	CO2 emissions (kt)
4	LKA	2003	21475.8	18881765437	12412.3
4	LKA	2004	21413	20662525941	12868.2
4	LKA	2005	21350.2	24405791045	13984.4
4	LKA	2006	21287.4	28279802451	12404.9
4	LKA	2007	21224.6	32350238663	13591.6
4	LKA	2008	21161.8	40713826321	12810.7
4	LKA	2009	21099	42066223971	12291.4
4	LKA	2010	21036.2	58636160849	13071.8
4	LKA	2011	21086.6	67753284135	15410.2
4	LKA	2012	21137	70447217164	17440.4
4	LKA	2013	21187.4	77000578207	14448.4
4	LKA	2014	21237.8	82528535573	17458.3
4	LKA	2015	21288.2	85140955517	19240.9
4	LKA	2016	21256.6	88012281910	23167.6
4	LKA	2017	21225	94376237832	23140.5
4	LKA	2018	21193.4	94493871351	21690.3
4	LKA	2019	21161.8	89014978319	23427.9
4	LKA	2020	21130.2	84440535699	21846.3
5	BTN	1990	25067.2	287765007.1	185.39
5	BTN	1991	25166.48	240294282.5	182.8
5	BTN	1992	25265.76	240233528.1	205.11
5	BTN	1993	25365.04	225973695.3	177.05
5	BTN	1994	25464.32	258954703.9	205.9
5	BTN	1995	25563.6	290490986.8	246.03
5	BTN	1996	25662.88	303408342.8	296.56
5	BTN	1997	25762.16	352229078.3	381.17
5	BTN	1998	25861.44	363458380.9	377.42
5	BTN	1999	25960.72	399311196.4	378.53
5	BTN	2000	26060	424448931	388.84
5	BTN	2001	26159.29	461479580.2	379.31
5	BTN	2002	26258.58	520846131.7	411.52
5	BTN	2003	26357.87	603999372.4	377.73
5	BTN	2004	26457.16	682577073.5	313.51
5	BTN	2005	26556.45	796938572	395.42
5	BTN	2006	26655.74	874989734.7	397.5
5	BTN	2007	26755.03	1168307575	398.71
5	BTN	2008	26854.32	1227809261	422.62
5	BTN	2009	26953.61	1234015142	396.83
5	BTN	2010	27052.9	1547990907	493.18
5	BTN	2011	27072.68	1777102586	744.2
5	BTN	2012	27092.46	1781280170	833.9
5	BTN	2013	27112.24	1756214304	908
5	BTN	2014	27132.02	1907090362	1012.4
5	BTN	2015	27151.8	2003596824	1042.1
5	BTN	2016	27171.6	2158971718	1228.4
5	BTN	2017	27191.4	2450366108	1309.5
5	BTN	2018	27211.2	2446867582	1454.3
5	BTN	2019	27231	2535655609	1433
5	BTN	2020	27250.8	2325185521	1035.2
6	MDV	1990	8.2	215043969.8	156.7
6	MDV	1991	8.2	244396761.9	159.6
6	MDV	1992	8.2	284875818	225.1
6	MDV	1993	8.2	322417837.2	202.6
6	MDV	1994	8.2	356014932.1	204.6
6	MDV	1995	8.2	398988955	261.4
6	MDV	1996	8.2	450382328	281.6

http://dx.doi.org/10.21511/ee.16(1).2025.02

Table A1 (cont.). CO2, forest area, and economic growth of SAARC countries

No.	Country	Year	Forest area (sq. km)	GDP (current US$)	CO2 emissions (kt)
6	MDV	1997	8.2	508223602.4	338.3
6	MDV	1998	8.2	540096397.6	311
6	MDV	1999	8.2	589239753.6	429.9
6	MDV	2000	8.2	624337145.3	462.2
6	MDV	2001	8.2	870031653.1	481.3
6	MDV	2002	8.2	897031250	614.4
6	MDV	2003	8.2	1052121055	528.5
6	MDV	2004	8.2	1226829563	693.1
6	MDV	2005	8.2	1163362438	626.9
6	MDV	2006	8.2	1575200391	790.5
6	MDV	2007	8.2	1868383461	810.6
6	MDV	2008	8.2	2271646188	870.6
6	MDV	2009	8.2	2345294875	916.6
6	MDV	2010	8.2	2588176055	963
6	MDV	2011	8.2	2774350163	1012.8
6	MDV	2012	8.2	2886163938	1144.6
6	MDV	2013	8.2	3295009231	1128.5
6	MDV	2014	8.2	3697353155	1355.2
6	MDV	2015	8.2	4109416450	1339.3
6	MDV	2016	8.2	4379134273	1465.9
6	MDV	2017	8.2	4754185599	1546.1
6	MDV	2018	8.2	5300949823	1776.1
6	MDV	2019	8.2	5609385434	1999.5
6	MDV	2020	8.2	3746329358	1454
7	PAK	1990	1447.4	40010423970	59026
7	PAK	1991	49392.37	45625336680	60305.8
7	PAK	1992	48916.84	48884672605	66977.8
7	PAK	1993	48441.31	51809999353	73749.6
7	PAK	1994	47965.78	52293471393	76253.6
7	PAK	1995	47490.25	60636071684	82737.2
7	PAK	1996	47014.72	63320170084	85821.1
7	PAK	1997	46539.19	62433340468	89362.5
7	PAK	1998	46063.66	62191955814	90190.3
7	PAK	1999	45588.13	62973856844	98773.3
7	PAK	2000	45112.6	82017743416	98374.1
7	PAK	2001	44695.07	79484403985	99837.2
7	PAK	2002	44277.54	79904985385	102325.6
7	PAK	2003	43860.01	91760542940	105663.5
7	PAK	2004	43442.48	1.0776E+11	118313.6
7	PAK	2005	43024.95	1.20055E+11	121608.7
7	PAK	2006	42607.42	1.37264E+11	132304.2
7	PAK	2007	42189.89	1.52386E+11	145813.3
7	PAK	2008	41772.36	1.70078E+11	140734.2
7	PAK	2009	41354.83	1.68153E+11	145337.9
7	PAK	2010	40937.3	1.77166E+11	140378.6
7	PAK	2011	40615.04	2.13588E+11	141690
7	PAK	2012	40292.78	2.24384E+11	143819.1
7	PAK	2013	39970.52	2.31218E+11	145993.7
7	PAK	2014	39648.26	2.44361E+11	154235.2
7	PAK	2015	39326	2.70556E+11	164152.3
7	PAK	2016	38682.4	3.1363E+11	181113.3
7	PAK	2017	38499.2	3.39206E+11	198738.8
7	PAK	2018	38085.8	3.56128E+11	186865.6
7	PAK	2019	37672.4	3.20909E+11	184096.3
7	PAK	2020	37259	3.00426E+11	184111.2

Note: BGD = Bangladesh; IND = India; NPL = Nepal; LKA = Sri Lanka; BTN = Bhutan; MDV = the Maldives; PAK = Pakistan.