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Drivers of Carbon Emissions in South Asia: Analyzing Economic Growth, Urbanization, Tourism, Industrialization, and Renewable Energy

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ABSTRACT

Rising CO_2 emissions pose a global challenge, including in South Asia. This study examines the determinants of CO_2 emissions—economic growth, urbanization, tourism, industrialization, renewable energy, agriculture, and forest area—using panel data (1990–2021) from South Asian countries. Dynamic Ordinary Least Squares (DOLS) and panel unit root tests reveal long-run relationships. Urbanization, tourism, and agricultural value-added significantly increase CO_2 emissions, while economic growth, renewable energy, and forest area negatively correlate with emissions. The findings suggest that energy-intensive urbanization, tourism, and agricultural expansion drive emissions, whereas renewable energy adoption and forest conservation mitigate them. Policymakers must prioritize sustainable urbanization, green tourism, and renewable energy transitions to curb emissions while fostering economic development.

1 Introduction

Degradation of the environment is currently the most difficult challenge that the entire world is attempting to address. The rise in population, the proliferation of consumer goods, and the advent of the Industrial Revolution are the primary causes of this issue. Baloch et al. (2023), state that the environment and its resources are deteriorating because individuals do not have enough environmental education, knowledge, understanding, and attitude. Emissions of carbon dioxide are the main driver of both environmental harm and climate change. Human activities that increase atmospheric CO2 emissions include burning biomass and fossil fuels, both of which produce greenhouse gasses. Carbon dioxide emissions have also gone up due to rising energy use, expanding economies, and the need to produce food for everyone. (Asumadu-Sarkodie & Owusu, 2016).

Economic growth and CO_2 emissions are significantly related. Economic growth is characterized by an increase in the production of goods and services during a certain timeframe compared to a prior year. The country's economic growth is enhanced by more economic activities, but it also results in higher CO_2 emissions. Energy consumption is vital for fostering economic activities; nonetheless, it adversely affects the environment by elevating carbon emissions and depleting resources. The environmental deterioration experienced by developing countries is a consequence of utilizing fossil fuel-derived energy to enhance economic operations. To enhance economic growth in developing nations, it is essential to expand these activities while also preserving environmental quality. When this transpires, enterprises employ fossil fuels to stimulate economic expansion, while worsening environmental circumstances due to their widespread utilization of these fuels. As a result, it is possible to assert that industrialization contributes to environmental degradation in a country (Wolde-Rufael & Menyah, 2010).

Urbanization pertains to the movement of people from rural to urban areas and the corresponding decrease in the rural population. Environmental degradation is also worsened by urbanization. Due to rapid population increase and economic development, urbanization is an inevitable phenomenon. Urban communities encroaching on agricultural regions may have disastrous repercussions (Shalaby, 2012). Urbanization is a major threat to arable lands in most major developing cities, where it has accelerated due to factors like globalization, significant economic restructuring, and a lack of rural employment opportunities (Jiang et al., 2013; Shalaby, 2012). Global cities serve as both hubs for innovation and growth for the world economy. Economic and social growth has been significantly accelerated by rapid urbanization. Urbanization has, however, also resulted in a host of environmental issues, ranging from local to global, such as increased energy use, local climate change, and pollution of the air, water, and land.

Tourism is an economic and social activity including traveling to new locations to experience different cultures, gastronomy, landscapes, and customs. Tourism is essential to promote the economic growth of the country. Mikayilov et al. (2019) regarding the Global Tourism Association, tourism is among the most rapidly expanding businesses & contributes exceeding 10 percent to the universal GDP. International tourist arrivals in 1950 began at twenty-four million but expanded to 166 million during 1970 and exceeded 1.442 billion in 2018 and are anticipated to surpass 1.8 billion by 2030. The enormous influx of tourists can lead to probable environmental deterioration despite its positive economic and job creation and income expansion benefits. Tourists' exposure to local pollutants destinations can be caused by a diversity of reasons, including heating, vehicle use, hard waste, noise, cluttering, dirt, oil and compounds, and architectural and painterly pollution. The quality of the ecosystem is also harmed by an unplanned, disproportionate, and crowded tourist population. It causes waste and pollution to skyrocket, services to deteriorate, and natural resources to be used excessively. Beyond capacity, the influx of tourists also brings about problems rather than advantages, such as soil degradation, garbage accumulation, air pollution, depletion of natural resources, and risks to biodiversity, socio-cultural habitats, and the pristine state of the land and sea (Andlib & Salcedo-Castro, 2021).

Renewable energy is a type of energy that comes from natural resources or processes that can be perpetually replenished. According to Xiong et al. (2014), energy resources play a crucial role in the economy and the process of economic development. According to Gabr and Mohamed (2020), there exists a robust relationship between energy consumption and the growth of the economy, with the former being a significant contributor to GHG emissions, specifically CO_2 emissions. However, increasing the usage of renewable energy has numerous possible benefits, including reducing emissions that cause climate change, diversifying energy portfolios, and lessening reliance on the fossil fuel energy sector. Renewable energy initiatives also make it possible to replace carbon-intensive energy sources. Expanding the availability of renewable energy could boost employment by creating roles in developing green technology (Belaïd & Zrelli, 2019). Environmental challenges can be addressed by the utilization of renewable energy sources such as wind, solar, and hydropower. Akella et al. (2009) that utilizing renewable energy can fulfill energy production requirements, improve environmental quality, and prevent pollution by substituting non-renewable technologies and non-degradable environmental standards.

1.1 Objective of the Study

The study aims to address the following primary objectives:

- To explore the impact of economic growth on CO_2 emission with in South Asian region.
- To assess the relationship of urbanization on CO_2 emission across South Asian countries.
- To analyze the environmental impact of tourism on CO_2 emission in nations of South Asia.
- To examine how industrial development contributes to CO_2 emission in South Asian countries.
- Analyze the impact of renewable energy consumption on CO_2 emission in South Asian region.

The study will provide important implications to the policymakers of South Asian economies about how economic growth, urbanization, tourism, industrialization, and the utilization of renewable energy are crucial to influencing carbon emissions. Considering the study's results, the representatives of the South Asian economies can design policies to promote green energy and reduce CO_2 emissions. The collaboration amid urbanization and CO_2 emissions will also provide important policy guidelines, as most of South Asia is experiencing higher urbanization. Therefore, suitable urbanization policies to promote vertical urbanization and reduce the level of CO_2 emissions are also suggested in a study.

2 Literature of Review

The literature review is an essential part of the research studies. This part of the research is crucial in determining the existing knowledge and finding a research gap. Therefore, this part is designed to present the literature review.

2.1 Studies related to the Urbanization & Impact of Economic Growth on Carbon Emissions

Different studies analyzed the effect of economic growth (EG) on carbon emissions such as Alnour (2021) investigated the correlation between environmental degradation (ED) and economic development in Turkey. The data utilized a study from 1970 to 2017. The research utilized the ARDL model for analysis of the data. According to the findings, economic growth has a short-term considerable beneficial impact on environmental degradation and a long-term positive but negligible impact. The study does not find any evidence of the existence of the EKC hypothesis.

The study in the case of OECD countries from 1994 to 2014 was conducted by (Balsalobre-Lorente et al., 2020). This study discovered the association among economic growth, foreign travel, globalization, EC, and carbon dioxide (CO_2) emissions. The empirical research showed that the use of energy, tourism, and EG amplifies climate change. International tourism and environmental degradation likewise have an inverted U-shaped relationship. Thus, globalization at later stages of development lessens the early-stage contribution of international tourism to climate change. Globalization perhaps reduces CO2 emissions associated with worldwide travel. The observed findings offered more justifications for developing regulatory frameworks that support energy efficiency and source of renewable energy to alter the remaining energy composition in OECD nations.

Similarly, Shaheen et al. (2020) examined the influence of Pakistan's GDP, use of energy, and urbanization on CO_2 emissions from 1972 to 2014. The outcomes exhibited that CO_2 emissions were considerably augmented by energy consumption and GDP but not by industrialization or urbanization. The results indicated that reducing the economic disparity between rural and urban areas, improving energy infrastructure, and implementing technology innovations could help Pakistan's carbon emission reduction efforts.

Majeed and Tauqir (2020) analyzed the effect of industrialization and urbanization on carbon emissions from 1990 to 2014 for 156 nations with different economic levels. Findings showed that industrialization and urbanization affected carbon emissions positively and statistically, but economic expansion affected environmental damage in different ways. In a similar vein, pollution rose as a result of economic development in all income brackets except high-income nations. Results demonstrated that increasing urbanization and industrialization were the main drivers of environmental degradation on a worldwide scale, but the impacts of economic growth, financial development, and energy consumption differed among nations with diverse stages of development. According to the results, the key reasons for environmental degradation were the rise in urbanization and industrialization. The study results suggested that green finance and other clean energy sources may facilitate the advancement of sustainable urbanization and industrialization.

2.2 Studies Related to the Tourism and Industrialization on Carbon Emissions

Chau et al. (2023) observed the things of tourism, economic development, and eco-innovation on ecological degradation in China using data from 1988 to 2020. The NARDL model was used to explore the connections between the variables. The outcomes showed that environmental deterioration was positively connected with foreign tourism revenues, spending, and tourist arrivals, in addition to GDP, national income, and inflation, sustainability-oriented eco-innovation showed a negative correlation in the China.

Different studies analyzed the impact of industrialization on environmental degradation such as Opoku and Aluko (2021) investigated how industrialization has impacted the environment. The study relied on data from 37 African states between 2000 and 2016 while implementing an analysis with the quintile regression model. The results of this study show industrialization has a significant impact on the environment. Industrialization was also found to cause environmental deterioration. Manufacturing organizations should embrace and use sustainable technologies in their industrial operations to mitigate environmental damage. Compliance with environmental regulations was essential to ensure that manufacturing activities would lead to the upkeep and expansion of a sustainable environment.

Appiah et al. (2021) investigated the relationship between use of energy, industrialization, and environmental degradation. In this study data was used from 1990 to 2016. This study showed that for sub–Saharan African countries, the use of fossil fuels, industrialization & urbanization had a positive relation with environmental degradation, regardless of energy usage, which has a considerable impact. The analysis showed that the causal aspect had a bidirectional causal mechanism for industrialization and CO_2 emissions and a unidirectional causal pathway for urbanization. The study suggested that encourage energy efficiency it will minimize environmental degradation.

2.3 Studies of the Impact of Renewable Energy Use on Carbon Emissions

Dagar et al. (2022) used dynamic panel estimation to assess the effect on environmental degradation of 38 OECD countries' financial development, natural resource availability, industrial output, consumption of renewable energy, and overall reserve. The studies utilized panel data from 1995 to 2019. The analysis estimated data using the GMM approach. In OECD countries, utilization of natural resources and energy consumption will help to slow down environmental degradation. In contrast, financial development, industrialization, and total reserve have the reverse effect.

Adebayo (2022) evaluated the effect of renewable energy usage on CO_2 emissions. In this study Canadian data were used from 1990 to 2018. The study utilized a state-of-the-art, dynamic ARDL method. It was found that globalization, renewable energy use, and political risk were inversely correlated with environmental degradation. The frequency domain causation experiment results indicated that long-term CO2 emissions in Canada may be forecasted by economic expansion, geopolitical risk, utilization of renewable energy, and globalization.

2.4 Studies of the Influence of Agriculture and Forested Regions on Carbon Emissions

Investigated by Göksu and Göçoğlu (2023) were the possible impacts on environmental degradation of factors such as internet utilization, afforestation, energy usage, urbanization and GDP per capita. Information spanning the years 1990–2020 was input into the ARDL model. In both models, the GDP per capita long-run elasticity was less than short-run flexibility. All variables were cointegrated in the long run. Regarding causation, there was a bidirectional causal relationship between internet usage, forestation, urbanization, and ecological footprint. There were one-way causation connections between carbon dioxide emissions and factors like internet use, the pace of forestation, and gross domestic product per person. The findings showed that using the internet increases energy usage, which worsens environmental damage; it also has certain positive externalities that help to counteract the damage.

(Khurshid et al., 2022) investigated whether Pakistan's sizable agriculture sector influenced CO_2 emissions. The analysis applied the NARDL model to data from 1971 to 2021. The findings demonstrated that agricultural production exhibits asymmetry in the context of globalization when exposed to both positive and negative shocks. When agricultural production experienced a positive shock, CO_2 emissions increased, and when agricultural production experienced a negative shock, CO_2 emissions fell. Additionally, economic globalization was positively correlated with GDP, use of energy, and economic globalization. Surprisingly, however, in the framework of globalization, trade, and urbanization were negative correlates of CO2 emissions. Climate change brought on by greenhouse gas emissions affects Pakistan's economy and the environment, necessitating several sustainable mitigation measures. Therefore, to reduce CO_2 emissions, our study advises Pakistani farmers to switch to organic farming.

Usman et al. (2022) examined the effects of tourism, EG, non-renewable energy, and agricultural value-added on CO_2 emissions in South Asian countries from 1995 to 2017. The findings showed that the development of the non-renewable energy sector, agricultural sector, economic growth, and tourism sector significantly contributes to environmental degradation, demonstrating their negative effects on the quality of the environment. However, consuming renewable energy has some potential to raise the region's environmental standards. However, there was a conservation hypothesis between agricultural and carbon emissions, and finally, there was a growth hypothesis between tourism and carbon emissions. This study provides some critical policy implications for South Asian countries to achieve their SDGs, consistent with these empirical findings.

It was observed in the literature that different factors are contributing to increased carbon emissions. Various studies showed that economic growth, population growth, tourists, industrialization, and agriculture increased global carbon emissions. The use of energy consumption and forestry area were the imperative factors to improve the environmental quality. However, it was observed in the literature that the intensity of carbon emissions varies among countries depending on their environmental conditions and income levels. The developed countries have low carbon emissions because they promote green energy sources to boost economic activities.

In contrast, developing countries have high carbon emission levels because they use fossil fuels to promote agricultural productivity, economic growth, and industrialization. Most of the countries of South Asia are developing countries, and they are facing high levels of carbon emissions. Analyzing the role of all variables like the energy consumption, industrialization, urbanization, international tourism, forestry area, productivity of agriculture, gross domestic product, and economic growth in influencing CO_2 emissions is crucial in these countries. No comprehensive study mutually considers urbanization, industrialization, tourism, agriculture, the utilization of renewable energy, and forest areas as a factor of carbon emissions. Therefore, the study's outcomes will contribute significantly to the literature by providing fresh insights how all the variables which mentioned above are influencing CO_2 emissions in South Asian countries. So, the study's findings will add a lot to the literature since they shed new light on how renewable energy usage, tourism, economic growth, urbanization, industrialization, agriculture, forest area, and economic development are impacting CO2 emissions in South Asian nations.

2.1 Conceptual Framework

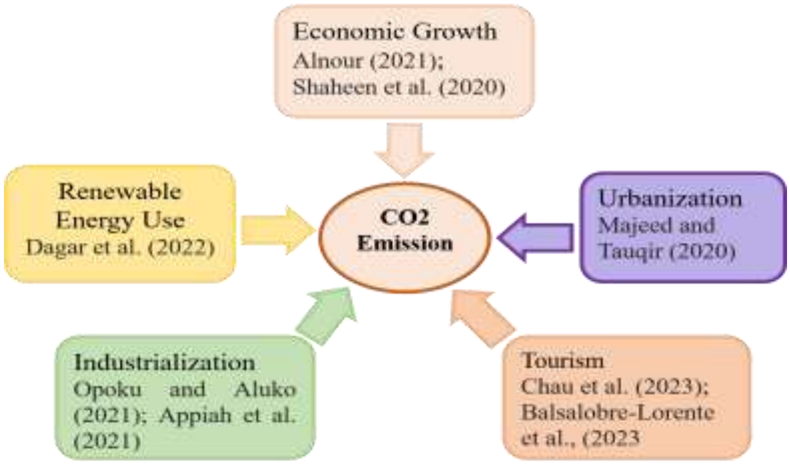

Figure 1
Conceptual Framework

This theoretical model shows how various variables affect CO_2 emissions. Economic growth, rise in urban population tourism, and industry area increase the demand for energy and the use of resources, which in turn leads to higher emissions (Alnour, 2021; Balsalobre-Lorente et al., 2020; Majeed & Tauqir, 2020; Shaheen et al., 2020). On the flip side, renewable energy use and other similar factors can promote carbon sequestration and sustainable behaviors, which in turn help reduce emissions (Adedoyin & Zakari, 2020; Appiah et al., 2021; Dagar et al., 2022; Göksu & Göçoğlu, 2023). By presenting a comprehensive picture of the environmental and economic factors influencing carbon emissions, the framework stresses the importance of well-rounded policies that foster economic growth without compromising environmental protection.

3 Models and Methodology

3.1 Model Specification

To evaluate the impact of economic growth, urbanization, tourism, industrialization, sustainable energy consumption, agricultural productivity, and forestry area on CO_2 emissions in South Asian Countries, the subsequent model has been formulated.:

CO_2 emissions = f (economic growth, urbanization, tourism, industrialization, renewable energy use, Agriculture productivity, forest area,)

$$CO_{2it} = \beta_o + \beta_1 EG_{it} + \beta_2 URB_{it} + \beta_3 TR_{it} + \beta_4 IND_{it} + \beta_5 RNE_{it} + \beta_6 AVA_{it} + \beta_7 FA_{it} + u_{it}$$

This study used CO_2 emissions as a dependent variable, while EG, URB, TR, IND, RNE, AVA, and FA were used as explanatory variables. Similarly, B_O and U_{it} are present to intercept and error terms, correspondingly, $\boldsymbol{\beta_1}$ ***to*** $\boldsymbol{\beta_8}$ The constants of the corresponding explanatory variables. Furthermore, 't' and 'I' show the time period and cross-sections of the research.

3.2 Data and Source

This research looks at the dynamic impact of Economic Growth **(EG)**, Urbanization **(URB)**, Tourism **(TR)**, Industrialization **(IND)**, Renewable energy consumption **(RNE)**, Agriculture productivity **(AVA)** and Forest Area **(FA)** on CO_2 emissions in South Asian Countries. For this purpose, a panel dataset from 1990 to 2021 of South Asian countries has been used. The data source is World Development Indicators (WDI). The South Asian nations included in the study for data analysis include Pakistan, Bangladesh, India, and Sri Lanka.

Table 1
Description of Variables

Code	Variables Name & Measurement Unit	Source	Expected Sign	Reasoning
Dependent Variables				
CO_2	CO_2 emission (Metric tons)	WDI		
Independent Variables				
EG	Economic Growth (Gross Domestic Product (Constant $)	WDI	(-/+)	Economic growth may lead to more CO_2 emissions as production and consumption rise (+). However, in economies transitioning to cleaner technologies, emissions may decline (-)
URB	Urbanization (Proportion of urban population relative to total population)	WDI	(+/-)	Urbanization could increase emissions through greater industrial and energy use (+). Conversely, sustainable urban planning may lower emissions (-)
TR	Tourism (Number of arrivals)	WDI	(+)	Tourism, particularly international, is associated with increased travel and energy use, leading to higher emissions.
IND	Industrialization (Industrial value-added growth rate)	WDI	(+)	Industrialization often involves energy-heavy processes, which can result in higher CO_2 emissions.
RNE	Renewable energy consumption as a percent of total energy consumption	WDI	(-)	A higher share of sustainable energy in the energy mix can reduce dependence on fossil fuels, lowering emissions.
Control Variables				
AVA	Agriculture value-added as a percent of GDP	WDI	(-/+)	Economies with a greater focus on agriculture may see lower emissions, as this sector generally requires less energy compared to industry (-). If the agricultural sector relies heavily on mechanization and fossil fuel-based technologies, the sign could potentially be positive (+).
FA	Forest area (square KM)	WDI	(-)	Forests act as carbon sinks, absorbing CO_2 and offsetting emissions, so an increase in forest area typically reduces net emissions.

3.2.1 Definition of Variables

CO_2 Emissions

One of the most significant issues facing contemporary society is the degradation of the environment, and carbon dioxide (CO_2)-containing greenhouse gas (GHG) are the main factors of climate change. In any economy, sustainable environmental development can lead to sustainable economic growth (Shahbaz et al., 2012). Most greenhouse gases produced by humans are made up of carbon dioxide (CO_2). The equilibrium amongst the solar energy that the earth fascinates and reflects into space is disturbed by the addition of man-made greenhouse gases to the atmosphere. This is causing the earth's surface temperature to rise, which will impact the climate, sea level, and global agriculture.

Economic Growth

The significant relationship between economic growth (EG) and CO_2 emissions. Environmental Kuznets Curve (EKC) theory shows the connection between carbon emissions and EG in emerging nations. This theory says that environmental degradation increases during the early stages of EG continuing until it reaches a certain level or a turning point in its association to income. Then it begins to fall (Heidari et al., 2015).

Urbanization

Urbanization is a process that causes a large population to gather in a relatively limited area permanently and is accompanied by increased settlement development, which will cause agricultural land to be converted into residential and agricultural uses (Mba, 2018). Urbanization can affect CO_2 emissions both favorably and unfavorably. Urbanization can result in greater energy use and emissions because of increased industrial activity, a demand for more transportation, and energy use in buildings. As cities expand, more energy is needed to run businesses, structures, and transportation networks, which increases CO_2 emissions (Sadorsky, 2014). On the other hand, metropolitan environments also present opportunities for more sustainable behaviors and resource utilization. Improved public transit systems, mixed-use development, and compact urban design can help cut down on the requirement for private vehicle use, overall energy use, & CO_2 (Zhang et al., 2017).

International Tourism

Tourism development encompasses the various activities associated with the creation and operation of facilities that provide services to both local and non-local visitors within a given area. The growth of infrastructure and land use for tourism often places significant emphasis on natural capital, leading to detrimental consequences such as soil destruction, sensitive pollution, the depletion of natural ecosystems, and the risk of type. The proliferation of tourism-related infrastructure and construction endeavors exerts a substantial influence on the degradation of ecosystems, the diminishment of biodiversity, deforestation, the peers of solid waste and manure, the extreme utilization of air and water resources, the emission of gases that donate to air and water pollution, and the exacerbation of change in environment Baloch et al. (2023); Azam et al. (2018).

Industrialization

The process of industrialization includes the installation of new industrial facilities and the expansion of existing ones to enhance production and meet market demands, thereby directly impacting a nation's energy consumption patterns. Industrial development plays a crucial role in driving economic growth by fostering cross-sectorial advancements. However, it is important to note that this progress is accompanied by an increase in a nation's energy consumption. Additionally, as more employment becomes available due to industrial development, more people are employed, improving their socioeconomic standing (Wang et al., 2020). In the beginning, when developing countries transform from rural to industrial economies, dew to transform a huge increase in industries as well as pollution also increase and significantly contributed to environmental deterioration (Patnaik, 2018).

Renewable Energy Use

Renewable energy is a strategic commodity for sustainable development (Guo et al., 2022). Many renewable energy sources, including solar, wind, waste, and biomass, are considered economical and environmentally friendly because they lessen pollution, improve energy security, alleviate the negative effects of climate change, and, ultimately, offer affordable electricity. Although there isn't a single definition for renewable energy like for other topics (Joseph, 2019), there are recurring themes when defining or explaining it. These include the requirements that any energy source must meet to be considered renewable: it must be self-renewing when consumed, durable over an extended period, and ecologically beneficial. According to Chel and Kaushik (2018), renewable energy is any form of energy produced in a way that is environmentally beneficial and allows the globe to minimize carbon emissions while still providing for the basic energy requirements of humanity (Oladeji, 2014).

Agriculture value-added

Large-scale energy consumption was a component of agricultural production mechanisms. The need for energy consumption rises along with the increase in agricultural production brought on by globalization. Most of the energy used in developing countries is from nonrenewable sources, increasing the amount of GHGs released into the atmosphere (Majeed & Luni, 2019). Consequently, agricultural expansion impacts the ecosystem (Gokmenoglu & Taspinar, 2018).

Forest Area

Forest plays a significant role in cutting CO_2 emissions by acting as a carbon sink and reducing the levels of greenhouse gasses in the atmosphere. Trees absorb CO_2 from the environment through photosynthesis and store it as carbon in wood and other organic compounds. Due to their high biomass and carbon content, forested areas can store large amounts of carbon. Additionally, the oxygen released by woodlands is essential for human and animal life. Therefore, preserving and regenerating forests can significantly reduce global CO_2 emissions.

3.3 *Estimation technique*

The study's methodology, as demonstrated in Figure 2, clarifies in a structured categorization. To begin with, the selection of data and methodology takes priority, followed by a comprehensive literature review and an establishing model. Subsequently, panel unit root tests are conducted on the dataset. Finally, Dynamic Ordinary Least (DOLS) analysis is employed to draw insightful conclusions from the data.

The following econometric approaches are employed on the data to achieve the study's objectives:

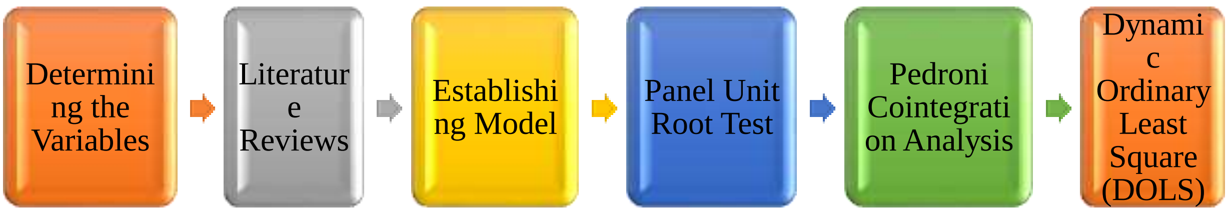

Figure 02
Methodology Approach

Unit Root Test

For accurate econometric analysis integration order is important. In this study we apply unit root test to assess the stationary characteristics of the data. Specifically, this study uses Phillips-Perron (PP) tests and extended the Dickey-Fuller test (ADF) as preliminary diagnostic tools. Identifying the issue of erroneous correlations was essential. This research allows for the selection of a suitable estimation technique for long-term parameter estimation.

Pedroni Cointegration Test

Pedroni proposed multiple cointegration tests utilizing a two-step methodology for both heterogeneous and homogeneous panels to evaluate the null hypothesis for individual regressors within the context of long-term relationships. The alternative hypothesis is accepted if residuals are integrated at a level instead of order first, which prevents us from rejecting the null hypothesis.

H_o: There is no long-run Cointegration

H_1: There is a long-run cointegration

Dynamic OLS (DOLS) Econometric Approach

The DOLS approach is commonly employed to evaluate long-term equilibrium relationships among variables in a non-stationary time series. Using Ordinary Least Squares (OLS) on integrated variables eliminates endogeneity biases and residual autocorrelation. Smooth at what time endogenic regressors exist, DOLS is unmoving and able to provide asymptotically well-organized and unbiased estimations of the long-term constants. It is also more effective than OLS when utilized with lower sample sizes. The principal and interval variance components make DOLS estimators resilient to omitted variables, autocorrelation, and stochastic trends. A p-value of 5% or 10% significance level from the DOLS coefficient estimation permits us to reject the hypothesis of zero coefficient. Insignificant p-values exceeding these thresholds indicate that we cannot rule out the possibility that the calculated coefficient is not equal to zero. DOLS is a widely utilized technique for assessing cointegration relationships, as it yields steady-state predictions of the interdependent variables' equilibrium over the long run.

4 Empirical Findings and Discussion

The table offers statistical data concerning the variables that were part of the study.

Table 2
Summary Statistical Analysis of the Variables

Variables	Mean	Max.	Min.	S.D.	Skew.	Kurt.
CO_2	5.154	6.390	4.035	0.712	0.165	1.946
EG	13.295	14.168	12.549	0.403	0.294	2.553
URB	1.750	1.960	1.542	0.135	-0.221	1.850
TR	5.887	7.253	5.017	0.605	0.618	2.419
IND	6.131	17.374	-5.745	3.464	-0.676	4.920
RNE	50.345	73.160	24.750	12.247	-0.046	2.465
AVA	22.869	34.699	11.633	5.571	0.091	2.366
FA	4.872	5.858	3.161	0.703	0.471	1.669

Abbreviations: CO_2, CO_2 Emissions; **EG**, Economic Growth; **URB**, Urbanization; **TR**, International Tourism; **IND**, Industrialization; **RNE**, Renewable energy use; **AVA**, Agriculture productivity; **FA**, Forest Area

Table 2 offers statistical data concerning the variables that were components of the study.

Table 2 illustrates the descriptive statistics of variables in terms of mean, maximum value, minimum value, SD, skewness, and kurtosis. It is discovered that CO_2 emissions yearly is 5.154, the largest value is 6.390, the lowest value is 4.035, SD is 0.712, the skewness value (0.165) specifies positively skewed data, and the kurtosis value (1.946) directs platykurtic distribution. Similarly, the mean value of renewable energy use is 50.345, the largest value is 73.160, the smallest value is 24.750, the SD is 12.247, the skewness value (-0.046) designates negatively skewed data and kurtosis value (2.465) indicates platykurtic distribution. Industrialization has a mean of 6.131, with a range from -5.745 to 17.374. The negative minimum suggests that some countries may report negative values for industrial output, possibly due to data anomalies or specific economic conditions. The standard deviation is 3.464, showing high variability. The negative skew of -0.676 indicates that the distribution is skewed towards higher values, and the high kurtosis of 4.920 indicates a highly peaked distribution.

Urbanization shows a mean of 1.750, with a relatively narrow range from 1.542 to 1.960. The small standard deviation of 0.135 suggests that urbanization levels are relatively stable across observations. The skewness of -0.221 is slightly negative, indicating a mild tendency toward higher urbanization values, while the kurtosis of 1.850 indicates a relatively flatter distribution. Tourism has a mean of 5.887, with a maximum of 7.253 and a minimum of 5.017. The small standard deviation of 0.605 reflects limited variation in tourism data. The positive skew (0.618) indicates a slight tendency for more countries to have lower tourism levels, and the kurtosis value of 2.419 suggests a moderately peaked distribution. Forest Area has a mean of 4.872, ranging from 3.161 to 5.858. The standard deviation of 0.703 reflects moderate variation. The skewness of 0.471 shows a slight positive skew, and the kurtosis of 1.669 suggests a relatively flat distribution, though not excessively so. Agricultural productivity has a mean of 22.869, with values spanning from 11.633 to 34.699. The standard deviation of 5.571 reflects substantial variability. The skewness of 0.091 indicates a near-symmetric distribution, and the kurtosis of 2.366 suggests a moderately peaked distribution. Gross Domestic Product has a mean of 13.295, with values ranging from 12.549 to 14.168. The low standard deviation of 0.403 indicates limited variability, and the positive skew of 0.294 indicates a tendency for countries with higher GDP values. The kurtosis of 2.553 suggests a slightly peaked distribution.

Overall, the variables in the dataset display a mix of symmetry and skewness, with some showing high variability (such as RNE and IND) and others exhibiting more stable distributions (such as UR and GDP). The kurtosis values indicate that most variables follow a relatively normal distribution, with some exhibiting slightly peaked or flatter distributions.

Table 3
Panel Unit Root Analysis

Variables	ADF Test		ADF-GLS Test		PP Test		Result
	Level	*1st diff*	*Level*	*1st diff*	*Level*	*1st Diff*	
CO_2	-1.55 (0.504)	-11.067 (0.000) *	-1.146 (0.250)	-11.104 (0.000) *	-1.599 (0.4797)	-11.067 (0.000) *	I (1)
EG	-2.163 (0.2211)	-11.11 (0.000) *	-2.092 (0.038) **	-11.043 (0.000)	-2.257 (0.188)	-11.11 (0.000) *	I (1)
URB	-1.585 (0.488)	-10.781 (0.000) *	-1.529 (0.129)	-10.824 (0.000) *	-1.737 (0.410)	-10.7956 (0.000) *	I (1)
TR	-1.671 (0.444)	-11.018 (0.000) *	-1.316 (0.191)	-11.055 (0.000) *	-1.721 (0.418)	-11.018 (0.000) *	I (1)
IND	-8.591 (0.000) *	-14.643 (0.000) *	-8.572 (0.000) *	-3.555 (0.000) *	-8.78 (0.000) *	-41.26 (0.000) *	I (1)
RNE	-1.116 (0.71)	-10.53 (0.000)	-0.776 (0.404)	-10.55 (0.000)	-1.473 (0.544)	-10.56 (0.000)	I (1)
AVA	-1.687 (0.440)	-11.125 (0.000) *	0.0212 (0.980)	-9.714 (0.000) *	-1.933 (0.316)	-11.176 (0.012) **	I (1)
FA	-1.511 (0.525)	-16.106 (0.000) *	-0.558 (0.0001) *	-16.135 (0.000) *	-2.004 (0.285)	-16.315 (0.000) *	I (1)

Note: *** Denotes the 1% significance level, ** the 5% significance level, and * the 10% significance level. The values in parentheses represent p-values, whilst the values above them denote test statistic values.

Panel unit root analysis is imperative to know a model's stationary level of variables. Based on the cointegration order, an appropriate technique for the estimation of parameters can be selected. The results of the Augmented Dickey-Fuller (ADF) test, ADF-GLS test, and Phillips-Perron (PP) test are displayed in the table. The outcomes of the entire test confirmed the variables being examined in a study are integrated at 1st difference. The 1st sequence of a combination of variables indicates that the dynamic ordinary least square (DOLS) method is superior to analyzing the long-run parameters of the variables.

Table 4
Pedroni Cointegration Analysis

Within Dimensions Cointegration Test	Statistic	Prob.
Panel v-Statistic	0.015	0.7426
Panel rho-Statistic	0.321	0.2491
Panel PP-Statistic	-4.652	0.0000
Panel ADF-Statistic	-5.547	0.0001
Between Dimensions		
Group rho-Statistic	2.019	0.6311
Group PP-Statistic	-3.910	0.0091
Group ADF-Statistic	-2.389	0.0351
Kao Residual Cointegration Test		
ADF	-2.383	0.0001

The findings from cointegration tests reveal long-term relationships that exist between variables within different dimensions of the model. For the within-dimensions tests, the Panel v-Statistic (0.015) and Panel Rho-Statistic (0.321) yield high p-values (0.7426 and 0.2491, respectively), suggesting no significant evidence of cointegration within the panel. However, the Panel PP-Statistic (-4.652) and Panel ADF-Statistic (-5.547), both with p-values of 0.0000, strongly indicate cointegration, showing that there is a long-term equilibrium relationship among the variables within the panel. For the between-dimensions tests, the Group Rho-Statistic (2.019) with a p-value of 0.6311 suggests no significant cointegration between the dimensions. In contrast, the Group PP-Statistic (-3.910) and Group ADF-Statistic (-2.389) with p-values of 0.0091 and 0.0351, respectively, provide evidence of significant cointegration at the group level, indicating a long-run relationship between the variables between dimensions. Lastly, the Kao Residual Cointegration Test with an ADF statistic of -2.383 and a p-value of 0.0001. The cointegration in the model shows that there is long-term relationship among the variables. Overall, the results suggest that there is strong evidence of cointegration both within the panel and across dimensions, particularly when considering the group-level and Kao tests.

Table 5
Results From the DOLS Estimator

Dependent Variable: CO_2 Emissions				
Variables	**Coefficients**	**Standard Error**	**T. Statistics**	**P. Value**
EG	0.1751	0.1733	1.0105	0.3149
URB	1.0124	0.18113	5.5898	0.0000***
TR	0.4262	0.1029	4.1414	0.0001***
IND	0.0061	0.0060	1.0294	0.3059
RNE	-0.0108	0.0030	-3.5326	0.0006***
AVA	0.0159	0.0067	2.3720	0.0197**
FA	-0.6297	0.0626	-10.0565	0.0000***
C	1.0243	1.9519	0.5247	0.601

Table 5 presents the result of the DOLS estimator. CO_2 emission is the dependent variable, while the explanatory variables are economic growth (EG), urbanization (URB), tourism (TR), industrialization (IND), use of renewable energy (RNE), agriculture productivity (AVA), and forest area. The DOLS outcomes found that the variables renewable energy use and forest area are negatively and considerably related to the CO_2 emissions, whereas the variables urbanization, tourism, and the value-added in agriculture are both positive and considerably connected to the Carbon emissions in South Asia. The variables of economic growth and industrialization are also positively but insignificantly related to CO_2 emissions.

Impact of Economic Growth on Co_2 Emissions

The results indicate that economic growth exerts a favorable albeit statistically insignificant effect on CO2 emissions in South Asia (β = 0.1751, p = 0.3149). This implies that while economic expansion may contribute to emissions, the effect is not strong or statistically validated within this model. The results highlight the region's rapid economic development and growing energy consumption, which are key factors in environmental degradation.(Usman et al., 2022). The absence of statistical significance, however, raises the possibility that other factors like changes in economic structure, increases in using alternative energy sources, or improving energy efficiency may play a more significant influence in determining CO2 emissions.

Impact of Urbanization on Co_2 Emissions

Urbanization is a significant factor that impacts the country's environment. Results show that urbanization (URB) is positively (β = 1.0124) and significantly (t-stat. = 5.5898; P = 0.0000) correlated with the CO_2 emissions in South Asia. The URB coefficient indicates that a one-unit enhancement in URB results in a 1.0124-unit increase in CO2 emissions. It suggests that society and properties moving from rural to urban areas due to economic output, energy structure, urban infrastructure development, transportation intensity, industrialization, and population-scale effects increase energy needs. (Huo et al., 2020). These results align with those of other researchers such as Faridi et al. (2018); Azam and Khan (2016); (Abbas et al., 2023).

Impact of Tourism on Co_2 Emissions

Tourism serves as a significant catalyst for economic expansion. It is originating that tourism (TR) is positively (β = 0.4262) and significantly (t-stat. = 4.1414; P-value = 0.0001) connected with the CO_2 emissions in South Asia. The TR coefficient indicates that for each unit increase in TR, CO2 emissions rise by 0.4262 units. It implies that international tourism businesses invest in infrastructure, such as the building of buildings or roads, as well as the implementation of tourism data and statement systems, all of which help them stay in touch with stakeholders, promote tourism practices, draw tourists, and give them a place to congregate. These costs boost the usage of ICT or construction technology, which results in GHG that harm the environment (Gulistan et al., 2020). These results also originated in the research by Baloch et al. (2023); Balsalobre-Lorente et al. (2018); Chau et al. (2023); Usman et al. (2022).

Effect of Industrialization on Co_2 Emissions

The results demonstrate that industrialization has a negligible and statistically insignificant effect on CO2 emissions, as evidenced by a coefficient of 0.0061. A one-unit rise in industrialization results in a marginal elevation of CO_2 emissions by 0.0061 units. The elevated p-value (0.3059) indicates that this link lacks statistical significance. Consequently, industrialization may not substantially influence CO_2 emissions in our assessment. Appiah et al. (2021); Abbas et al. (2023); Opoku and Aluko (2021).

Impact of Renewable Energy on Co_2 Emissions

Renewable energy use is imperative to decline CO_2 emissions. It is found that renewable energy use (RNE) is negatively (β = -0.0108) and significantly (t-stat. = -3.5326; P = 0.0006) associated with the CO_2 emissions. The RNE coefficient points out that as RNE is enhanced by one unit, the CO_2 emissions lead to a decline of -0.0108 units. It suggests that renewable energy helps maintain a clean environment because it exchanges traditional technologies that rely on fossil fuels (Bilgili et al., 2016).

In total, renewable energy does not harm the environment because it is endless and sustainable in contrast to non-renewable energy. Because of its simple implementation and cheap maintenance costs, it guarantees energy security and has economies of scale and spillover benefits Prandecki (2014). These results are also found by Kirikkaleli et al. (2022); (Abbas et al., 2023).

The Effect of Agriculture Productivity on Co_2 Emissions

The agriculture sector is crucial to influencing the environmental conditions of a country. It is found that agriculture productivity (AVA) is positively ($\beta = 0.0159$) and significantly (t-stat. =2.3720; P-value = 0.0197) associated with the CO_2 emissions in South Asian countries. The AVA coefficient demonstrates that AVA enhances by one unit, the CO_2 emissions increase by 0.0159 units. It suggests that the manufacturing of various fertilizers, energy from fossil fuels, and emissions from the production of animals and crops, which are the key sources of GHG emissions, are all involved in modern agriculture (Qiao et al., 2019). These outcomes align with some previous studies such as Usman et al. (2022); Balsalobre-Lorente et al. (2018); Jebli and Youssef (2017).

Influence of Forested Regions on Co_2 Emissions

Forests are considered an important source to improve environmental quality. It is originating that forest area (FA) is negatively (-0.6297) and significantly (t-stat. = -10.0565; P= 0.0000) associated with the CO_2 emissions in South Asia. The FA coefficient shows that as FA rises by one unit, the CO_2 emissions decrease by -0.6297 units. It suggests that trees absorb CO_2 emissions from the environment during photosynthesis, aiding in environmental protection. This aspect highlights how crucial forests are for lowering CO_2 emissions (Stern, 2006). These outcomes are also originated by (Waheed et al., 2018); Akinbami et al. (2003).

5 Conclusion and Suggested Policies

The analysis looks at the decisive influence of economic growth together with urbanization tourism industrialization renewable energy and agriculture and forestry areas on CO2 emissions in South Asian countries. A panel data set spanning from 1990 to 2021 covers South Asian countries for analysis purposes. Data acquisition occurred through the World Development Indicators (WDI). Various panel unit root tests, Pedroni cointegration tests, and DOLS methodologies are employed for data analysis. The DOLS approach is commonly employed to evaluate long-term balance associations among non-stationary time series variables.

It is found through empirical investigation that CO_2 emissions are directly correlated to increase in GDP, rise in urban population, tour sector, industrial development, and agriculture productivity. In contrast, CO_2 emissions are negatively correlated to renewable energy use and forest area. DOLS outcomes found that the variables, urbanization, tourism, and agriculture value-added are positive & significant related to the environmental degradation, although the renewable energy use and forest area are negatively and significantly related to the CO_2 emissions in nations of South Asia. The variables of economic growth and industrialization are also positively but inversely related to CO_2 emissions. It is concluded that economic growth, urbanization, tourism, and the agriculture sector are promoting CO_2 emissions due to the increasing use of energy. Therefore, it is strongly advised that South Asian economies increase their use of alternate, cleaner, and renewable energy sources while reducing their use of various fossil fuel foundations to achieve lesser environmental contamination levels.

Suggested Policies

The findings of this research enhance comprehension of the intricate interconnections among various variables and carbon dioxide emissions. These insights may function as the foundation for policy suggestions that aim to reduce the adverse consequences of CO2 emissions within the framework of selected countries. The following are the recommendations suggested by the researcher:

- Foster enduring economic growth by emphasizing the quality of economic growth rather than its sheer magnitude. This involves advocating for the growth of enterprises with diminished carbon emissions, supporting improved how to save energy, and directing resources near renewable and sustainable energy options. Applying strategies that dissociate economic development from emissions generation could be advantageous.
- Although the correlation between economic growth and CO_2 emissions is weak, achieving a harmonious equilibrium between economic growth and environmental conservation is paramount. Concurrently, sustain endeavors to advocate for policies that support energy efficiency and greener technology while remaining vigilant regarding emissions in economic growth.
- Develop an urban planning approach that emphasizes expanding green areas, enhancing public transit systems, and constructing energy-efficient buildings. Promoting compact, walkable neighborhoods can significantly improve the quality of life. Support the implementation of policies that protect green spaces and promote sustainable land use in cities.
- Nevertheless, industrialization can contribute to emissions, albeit in a relatively weak correlation. Green industrialization should be the primary objective, which can be achieved by promoting environmentally friendly technology, enforcing emission limits, and developing responsible business practices. Adopt measures to regulate pollution and promote the growth of environmentally conscious sectors.
- Support the development of environmentally conscious visitor practices by adhering to the tenets of sustainable travel. Promote the adoption of ecologically sustainable transportation alternatives, energy-efficient lodging establishments, and ethical tourism methodologies. Both crucial objectives are preventing congestion in ecologically sensitive areas and promoting tourism activities that leave minimal carbon footprints.
- Encourage the adoption of renewable energy by introducing clear regulations, providing financial support, and offering incentives to drive investment and development in the sector. Investment in renewable energy substructure and study is advised to enhance the share of renewable energy sources in the overall energy mix. Set specific goals and timelines to facilitate the incorporation of renewable energy sources.

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