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Measuring the Long-run Effect of Economic Growth, Population Aging, and Unemployment on Carbon Emissions in South Asia

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Abstract

During the last two decades, South Asia has faced extreme climate change events of heatwaves, floods, storms, droughts, and fires, affecting economies and millions of people. Meantime, the region has also experienced a notable change in economic growth, population aging, and unemployment rate. However, the carbon implications of these factors are still limited, and it requires further exploration to understand their association with carbon emissions for environmental sustainability. Thus, the prime aim of this study is to empirically evaluate the effect of economic growth, population aging, and unemployment on carbon emissions in South Asia by controlling trade and renewable energy. For this, panel data from 1996 to 2020 for Bangladesh, India, Nepal, Pakistan, and Sri Lanka have been used for empirical analysis. The study employs fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) estimation techniques using Stata and EViews software. Economic growth, population aging, and trade openness increase carbon emissions while unemployment and renewable energy reduce them. This study also confirms an inverted U-shaped association between income and carbon emissions in South Asia.

Keywords: CO2 emissions, aging, unemployment, trade openness, renewable energy, South Asia.

1. Introduction

Carbon emissions are the main contributor to climate change and global warming. Caron emissions during the last three decades have increased in the atmosphere due to demographic changes, expansions in the economies, trade, and energy consumption that threaten humanity and ecology in the world (Allan et al., 2023; Mitić et al., 2023; Weiland et al., 2021; Xia et al., 2022). The world is focusing on mitigating global warming and reducing carbon emissions (Wang et al., 2023). After the Paris Accord in 2015, many developed countries started their efforts to reduce 50 percent of emissions by 2030 and to stay below 1.5 °C of global warming (Rogelj et al., 2016). However, developing countries including South Asia are facing difficulties in achieving these targets. Moreover, South Asia is ranked at the top of environmental vulnerability risk (Fan et al., 2020). South Asia contained one-fourth of the World's population with higher levels of poverty and unemployment. To improve the lives of millions of people, the region is focusing on economic growth and industrialization. According to the World Bank report, the demand for energy in South Asia has risen by 50 percent since 2000 and is expected to double within the next decades in the domestic and industrial sectors. For energy, South Asian countries are relying on fossil fuels. Burning of fossil fuels increases carbon emissions and hurts the environmental quality. In the meantime, along with these economic activities, South Asia has faced significant changes in population aging, unemployment, and renewable energy consumption in South Asia. Thus, knowing about climate change and its determinants is essential to achieving the environmental objectives outlined in the Paris Agreement and sustainable development goals. For this, empirical research considering economic and non-economic factors is crucial for effective environmental policies in South Asia.

Today the World is facing a significant change in population demography. Although, the world's population passed the 8 billion milestones on November 15, 2022, but researchers believe that in recent times population aging is a big challenge rather than population growth (Yuan et al., 2024). The share of population aging is increasing in the globe due to better health facilities, income levels, and life expectancy (Yuan et al., 2024). Only in Asia-Pacific, 651 million people are living at age 60 years or above comprising 14 percent of the total population (ESCAP, 2022). The rising share of older people along with extreme weather and climate change is a big challenge for this region. Although the aging process in South Asia is slow compared to other industrial countries, it will soon be an issue for sustainable economic growth and the environmental quality in the region (Abbas et al.,2023). The impact of population growth on carbon emissions is extensively studied, but the impact of population aging on carbon emissions is limited particularly in developing countries. Moreover, the empirical results of existing studies focusing on population aging are inconclusive. Some researchers believe population aging increases carbon emissions because older people stay at home and consume more energy (Bardazzi & Pazienza, 2017). Another study found that the expenditure shares for food, furniture, health, and energy increase with age (Lührmann, 2005). For a better understanding of carbon emissions, special attention is needed to understand how aged people contribute to carbon emissions in South Asia.

Along with population aging, unemployment is another macroeconomic factor that influences economic growth and carbon emissions. Unemployment remains a big challenge for South Asia, and it is becoming critical over time. Unemployment is a situation where people actively seek a job but cannot find a job. Unemployment in South Asia was the highest at 5.4 percent in 2019 compared to the rest of Asia (Gomis et al., 2020). Unemployment increases poverty, unequal distribution of wealth, and social unrest, but its environmental-related implications have not been explored extensively. Earlier studies showed a negative relationship between unemployment and carbon emissions and confirmed environmental Phillips curve (Bhowmik et al., 2022; Tariq et al., 2022). Unemployment reduces individual income and consumption of goods and services and decreases carbon emissions. The other reason is that resources remain unutilized when the economy works under full employment, and there will be low carbon emissions (Bhowmik et al., 2022). Other researchers believe unemployment is not suitable for the environment. To provide more jobs, economies focus on industrialization, increasing energy consumption. Carbon emissions increase because industries in developing countries are pollution-intensive and rely on conventional sources of energy (Dogan et al.,2021). Considering mixed results, understanding unemployment's effect on South Asia's carbon emissions is essential for future sustainable economic growth.

We complete our analysis by incorporating trade openness and renewable energy consumption in the model which are significant for environmental quality. Trade openness brings higher economic growth and employment (Rahman et al., 2020). In contrast, trade openness expands economies and increases energy demand. The burning of fossil fuels is deteriorating environmental quality. Some researchers believe trade brings technology and improves environmental quality. On the other hand, renewable energy is another vital factor for environmental quality. Paris Agreement and sustainable development goals (SDG7) are committed to decarbonizing the economies by reducing reliance on fossil fuels and encouraging the use of renewable and clean energy (Chaudhury et al., 2023). Clean and green energy, an alternative source of fossil fuels, reduces carbon emissions (Rehman et al., 2023). Therefore, including trade and renewable energy is essential in our empirical analysis to understand the association between the considering variables and carbon emissions in South Asia.

Based on this background, the prime objective of this study is to seek the relationship between population aging, unemployment, and carbon emissions along with trade openness and renewable energy consumption in the context of South Asia which was missing in earlier studies. Moreover, this study validates the existence of the Economic Kuznets Curve hypothesis and Environmental Phillips Curve theory in South Asia in the light of economic and demographic factors. Our study selects the South Asian region as a sample for analysis because the region is the most populous, emerging, and vulnerable to climate change. Economic growth between 2010 and 2018 increased faster than the global average of 3 percent. Energy consumption is extremely high. The unemployment rate is 6.90 percent, higher than the World average of 5.5 percent. Nearly one out of five persons will be aged by 2050 in South Asia. These countries also face tradeoffs between growth and the environment, creating a grave concern over environmental quality. The control of carbon dioxide emissions without the loss of income and employment is the primary concern for South Asian policymakers.

The novelty of the study can be argued in the following points. First, the empirical findings are based on theoretical frameworks that enrich the literature concerning the association between economic and non-economic factors and carbon emissions in South Asia. Secondly, this study selected South Asia as a sub-sample for empirical analysis where population aging, unemployment, and carbon emissions are increasing but the association between these factors was missing. Lastly, the study results obtained by using both FMOLS and DOLS estimation techniques are reliable and consistent. We consider the issue of slope heterogeneity and cross-sectional dependency. The results of these studies will be helpful for future policy formulation.

The later sections of this paper are given in the following sequence. Section 2 presents a theoretical and empirical literature review. The research method, including data, variables, and estimation context, is presented in section 3. Section 4 contained the results and discussions of the study. Section 5 expresses the conclusion along with policy suggestions and limitations of the study.

2. Literature Review

2.1 Theoretical Linkages

The relationship between economic growth and environmental degradation has been extensively analyzed during the last two decades and revealed that an inverted U-shaped relationship exists between the level of economic growth and CO2 emissions. It is known as the Environmental Kuznets Curve (EKC) hypothesis. The current study's growth and environmental nexus are theoretically explained by this EKC hypothesis first proposed by (Grossman & Krueger, 1991) who states that the country's environmental losses and solution lie in income growth. Environmental degradation increases at the earlier stage of economic growth; however, after a certain income level, environmental quality improves due to technological innovation and a higher level of income.

The environmental Phillips curve is another theory to express the relationship between unemployment and carbon emissions put forward by (Kashem & Rahman, 2020). According to EPC, a negative association exists between carbon emissions and unemployment. Earlier, Okun's law was a basic model to express the negative relationship between unemployment and income, but carbon emission was missing. There are two channels (growth and preference channel) used to understand the theoretical linkages between carbon emissions and unemployment. Unemployment through growth channels reduces economic growth, energy consumption, and carbon emissions. In contrast, unemployment through preference channels diminishes consumers' income and preferences in favor of improved environmental quality and environmentally friendly goods (Bhowmik et al., 2022).

However, no exact theoretical concept in the literature is available to express the relationship between population aging and carbon emissions. Nevertheless, we can understand and express this relationship with the help of the life cycle model and overlapping generation model. An individual's lifetime earnings are like a hump-shaped; they increase with experience and age and then go down at retirement. This life cycle earning pattern is significant to understanding the change in consumption and investment patterns of old age people. People feel their income will decrease at retirement, so they save more during their employment period and use these savings while retired. Similar findings that the rate of saving and investment decline as people age are observed by (Cutler et al., 1990). The Over Lapping Generation model is the natural framework to understand the life-cycle behavior of investment in human capital, saving and consumption after retirement, and the implications of allocating resources across the generations.

2.2 Empirical Background

The primary determinant affecting carbon emissions is income. Researchers are focusing on observing this growth and carbon emissions nexus by testing the Economic Kuznets Curve hypothesis but this association is not evident and inconclusive (Frankel & Rose, 2005). The economic condition of the nations and their environmental policies at each stage of economic development will produce different effects on the environment. Ahmed et al. (2017) investigated the association between energy consumption, population growth, income, trade, and carbon emissions in South Asia from 1971 to 2013 and confirmed the existence of the EKC hypothesis. Economic growth, industrialization, and trade are vital in reducing unemployment and poverty in developing countries. These activities increase energy demand, and the burning of fossil fuels, the primary source of energy in South Asia, is deteriorating environmental quality (Thakur & Jayaram, 2024). Mehmood and Tariq (2020) also highlighted the importance of trade, industrial development, and economic growth and their related impacts on carbon emissions in South Asia from 1972 to 2013. The findings of the study based on ARDL revealed a U-shaped relationship between carbon emissions and income in Nepal, Afghanistan, Bangladesh, and Sri Lanka while an inverted U-shape association in Bhutan and Pakistan. Leitão et al. (2021) initiated a study on BRICS economies, i.e., India, China, Brazil, Russia, and South Africa, confirm the link between the Kuznets environmental curve and economic complexity from 1990 to 2015 by utilizing FMOLS and DOLS. Similarly, Balsalobre-Lorente et al. (2022) also confirm the existence of EKC in Portugal, Ireland, Italy, Greece, and Spain countries from 1990-2019.

Trade openness helped economies to grow faster and increase their income. However, this growth trend has increased energy demand and created environmental issues. Shahbaz et al. (2017) evaluate the effects of trade openness on carbon emissions in high-, low- and middle-income countries and find that trade impedes environmental quality. Wang and Zhang (2021) measure the effects of trade openness on carbon emissions from 1990 to 2015 using data from 182 countries. The results found a heterogeneous impact of trade on carbon emissions. Trade increases carbon emissions in low-income countries while reducing it in high-income countries. (Ahmed et al., 2017) evaluate the impact of trade openness on carbon emissions in South Asia. The study results obtained through FMOLS revealed that the trade deteriorated environment quality in South Asia from 971 to 2013. Moreover, the study also found an existing Economic Kuznets Curve attached to South Asia's income level. Similarly, Sun et al. (2019) measured trade openness effects on carbon emissions for 49 Built and Road initiatives countries. The results revealed that trade increases carbon emissions in all countries.

Population aging increases carbon emissions because older people consume more energy at home (Bardazzi & Pazienza, 2017). Yuan et al. (2024) also observed the same phenomenon between aging and energy consumption while considering the rural and urban populations in 39 provinces of China. Moreover, the expenditure shares for food, furniture, health, and energy increase with age (Lührmann, 2005). Another research paper develops the relationship between carbon dioxide emissions and the dynamic process of demographic transition within the context of OECD countries (Menz & Welsch, 2012). The investigation suggests that consumption patterns directly affect emissions and might exhibit nuanced dependencies on individuals' positions within their life cycles and the specific birth cohorts to which they belong. By harnessing a comprehensive panel dataset spanning 26 OECD countries over the temporal expanse from 1960 to 2005, the study unearths compelling evidence affirming the substantive influence of life-cycle effects and cohort effects within the broader macroeconomic framework of carbon emissions. The empirical outcomes illuminate that diverse consumption patterns appear across different life stages, and the generational cohorts significantly shape these patterns and contribute to the overarching carbon emission dynamics. Abbas et al., (2023) found a positive association between population aging and carbon emissions in South Asia while observing the effects of urbanization and institutional quality on carbon emissions from 1996 to 2019. Similarly, Mehmood and Tariq (2021) while evaluating the impact of evolving population dynamics and their social, economic, and ecological challenges from 1990 to 2016 in South Asia highlighted a discernible connection between age structure and CO2 emissions in the long term across all four countries of South Asia. Against the backdrop of the 2015 Paris Agreement and China's independent emission reduction commitments, Yu et al. (2018) recognize the influential factors of CO2 emissions within the context of China's current demographic and industrial configuration. The outcomes revealed that the population's aging, industrial structure, and per-capita income positively influence the growth in CO2 emissions.

In the literature, a very limited number of studies consider unemployment for the environment need further investigation. Xin et al. (2023) address this gap by employing a robust autoregressive distributed lag (ARDL) model to measure the association between education, unemployment, and CO2 emissions within China from the period 1991 to 2020. The empirical evidence revealed that unemployment increased CO2 emissions in the long run. Kashem and Rahman (2020) tried to evaluate the association between unemployment and carbon emissions in OECD and Asian countries from 1990 to 2016 by taking trade, GDP, and financial uncertainty in the model. The empirical results derived through fixed effects, random effects, and feasible generalized least squares revealed that unemployment reduces carbon emissions. Another study started in the USA from 1985 to 2018 observed a negative association between carbon emissions and unemployment by using dynamic ARDL and variables related to trade, fiscal and monetary uncertainties (Bhowmik et al., 2022). A study on South Asia confirms this negative relationship between carbon emissions and unemployment from 1991 to 2019 along with growth, energy consumption, and the use of renewable energy in the model (Tariq et al., 2022).

2.3 Research Gap

A detailed description of the literature review is given. Still, the relationship between GDP growth and CO2 emissions alone cannot be analyzed, so various other variables are used to examine their impacts on CO2 emissions. Only a few studies used South Asian subsamples for empirical analysis under EKC. Secondly, empirical analysis of population aging and the environment is mainly based on developed countries, and their results are inconclusive. Thirdly, no prior study measures unemployment's impact on South Asia's carbon emissions, population aging, and economic growth. This literature gap motivated further analysis on this topic. This research includes the population aging and unemployment, non-renewable and trade openness on CO2 under the EKC framework. This makes this research unique and enhances our understanding of carbon emissions and factors affecting carbon emissions in South Asia. A proper theoretical foundation also makes this study unique. We used both FMOLS and DOLS estimation techniques for empirical results. We also consider the issue of cross-sectional dependency and slope heterogeneity before long-run estimation.

3. Research Method

3.1 Data and Variables

This research uses panel data to measure the long-run effects of economic growth, population aging, unemployment rates, and carbon emissions across Bangladesh, India, Nepal, Pakistan, and Sri Lanka spanning from 1996 to 2020. Trade openness and renewable energy consumption were introduced as control variables. The data for all considered variables were obtained from World Development Indicators, a database of the World Bank. Carbon dioxide emissions are the dependent variable, measured in metric tons per capita. Gross domestic product, population aging, and unemployment were identified as primary independent variables, while trade openness and renewable energy consumption were considered control variables. Further elaboration on these variables is presented in Table 1. The selection of the timeframe and sample was guided by data availability and alignment with sustainable development goals.

3.2 Model Specification

Based on the theoretical background, this study applied the Economic Kuznets Curve hypothesis given in equation (1), where Y is used to measure GDP, Y^2 is used to measure GDP square, X is the set of explanatory variables in the model and script epsilon is the error term. The necessary condition for the validation of the Economic Kuznets Curve (EKC) hypothesis is the positive sign of the slope of GDP and the negative sign of the GDP square, respectively (Al-Mulali et al., 2015; Apergis & Ozturk, 2015). This inverted U-shaped directional association stands for the evolutionary impact of national income on carbon emissions per capita. This relationship is expressed in the following equation.

$$ln\,CO_{2it} = \alpha + \beta_2 lnY_{it} + \beta_2 (lnY_{it})^2 + \beta_3 lnX_{it} + \varepsilon_{it} \qquad (1)$$

After incorporating explanatory variables in the model, the empirical framework of the current study can be explained as follows.

$$ln\,CO_{2it} = \alpha + \beta_1 lnAGNG_{it} + \beta_2 lnGDP_{it} + \beta_3 (lnGDP)^2{}_{it} + \beta_4 lnRE_{it} + \beta_5 lnTRDO_{it} + \beta_6 lnUNR_{it} + \varepsilon_{it} \qquad (2)$$

Here, t is used to express the year (1996 to 2020) and *i* stands for the selected South Asian countries $ln\,CO_{2it}$ is the natural logarithm of carbon dioxide emissions metric tons per capita of the country *i* in the year t. *ln*GDP is the natural logarithm of gross domestic product per capita; $(lnGDP)^2$ is the square of gross domestic product per capita; *ln*AGNG is the natural logarithm of the population aging (65 years and above), *ln*UNR expresses the unemployment rate, *ln*RE denotes the natural logarithms of renewable energy consumptions and *ln*TRDO is the natural logarithm of trade openness. $\boldsymbol{\alpha}$ is constant; β1 to β6 are the slope coefficients of relevant factors, and ε is the random error term. We take the natural logarithm of all variables for empirical analysis to address normality and homoscedasticity issues.

Table 1: Details of the Variables

Variable	Description	Nature	Data source
CO_2	Carbon dioxide emissions metric ton per capita	Dependent Variable	WDI
AGING	Population ages 65 and above (% of the total population)	Independent Variable	WDI
GDP	Gross domestic product per capita (constant at 2015 US$)	Independent Variable	WDI
TRDO	Trade openness (% of GDP)	Independent Variable	WDI
RE	Renewable energy (% of final energy consumption)	Independent Variable	WDI
UNR	Total unemployment (% of the labor force)	Independent Variable	WDI

Source of data: World Development Indicators (WDI) data is available at: https://databank.worldbank.org/source/world-development-indicators

4. Results and Discussion

Our empirical results start from descriptive analysis followed by checking the heterogeneity, cross-sectional dependency, stationary of time series variables, and panel cointegration tests. After that, the long-run results are obtained by using FMOLS and DOLS estimation techniques.

4.1 Descriptive Statistics

In our analysis, the descriptive statistics, including the variables' mean, median, and standard deviation, are discussed in Table 2. There are ¬¬120 observations in the data. A higher dispersion has been seen in the values of carbon emissions, GDP square, unemployment rate, and population aging, while a lower dispersion has been observed in GDP, renewable energy, and trade openness. The values of the pairwise correlation matrix presented in Table 3 demonstrate that GDP, AGNG, and UNR are positively correlated with carbon emissions, while RE and TRDO are negatively correlated with carbon emissions. Moreover, the results of the correlation matrix show no evidence of multicollinearity in the data because all off-diagonal values of most of the variables are lower than 0.70 except population aging and GDP.

Table 2: Summary Statistics

	ln CO_2	**ln GDP**	**ln GDPS**	**ln AGNG**	**ln UNR**	**ln RE**
Mean	-0.70	7.06	1.61	1.11	3.99	3.73
Median	-0.42	6.98	1.55	1.41	3.94	3.74
Maximum	0.59	8.35	2.38	2.43	4.51	4.48
Minimum	-2.42	6.23	1.24	-0.92	3.42	3.08
Std. Dev.	0.80	0.53	0.25	0.81	0.29	0.32
Observations	120	120	120	120	120	120

Table 3: Correlation Matrix

Variables	***ln* CO2**	***ln* GDP**	***ln* GDPS**	***ln* AGNG**	***ln* UNR**	***ln* RE**	***ln* TRDO**
ln CO2	1						
ln GDP	0.649*	1					
ln GDPS	0.62*	0.98*	1				
ln AGNG	0.407*	0.874*	0.88*	1			
ln UNR	0.231	0.337*	0.33*	0.503*	1		
ln RE	-0.716*	-0.366*	0.34*	-0.075	-0.192	1	
ln TRDO	-0.052	0.416	0.42*	0.579**	0.389*	0.291*	1

* Significant at 1 percent

4.2 Cross-sectional Dependency and Slope Heterogeneity Test

Before panel data estimation, the existence of cross-sectional dependency and slope homogeneity in the data is one of the most critical diagnostics tests in panel analysis. The empirical results would be biased, unreliable, and inconsistent in the data's presence of CSD and slope heterogeneity. In this globalized world countries are interconnected via trade, cultural, and social networks and pass any change in one region to other regions via spillover effects (Ahmad et al., 2021). For this purpose, this study utilizes the cross-sectional dependency test (CD-test) proposed by (Pesaran, 2004, 2015). The results of the CD-test in Table 4 uniformly rejected the null hypothesis and accepted the alternative hypothesis of cross-sectional dependency in the data. Next, to check whether slopes are homogenous or heterogeneous this study utilized Pesaran and Yamagata's slope heterogeneity test (Pesaran & Yamagata, 2008). The results mentioned in the lower part of

Table 4 rejected the H_0 of slope homogeneity and confirmed the slope heterogeneity in the data.

Table 4: Cross-sectional Dependency and Slope Heterogeneity Test

Variable	**CD-test statistic**	**P-value**
ln CO2	13.53*	0.00
ln GDP	15.25*	0.00
ln GDPS	11.81*	0.00
ln AGNG	14.84*	0.00
ln UNR	2.54**	0.01
ln RE	13.68*	0.00
ln TRDO	2.O3 *	0.04
Slope heterogeneity test		
	Statistics	**P- Value**
Δ	6.10*	0.00
$\Delta_{adjusted}$	7.24*	0.00

Stata Results. *= Null hypothesis is rejected at 1 percent significance level

**= Null hypothesis is rejected at 5 percent significance level.

4.3 Stationarity Test

We applied second-generation Im, Pesaran, and Shin (CIPS) and the cross-sectional augmented Dickey-Fuller (CADF) unit root tests to know the stationarity among the variables. Both tests are proposed by (Pesaran, 2007). These tests provide better results in the presence of CSD and slope heterogeneity across units in dynamic panels as compared to first-generation unit root tests. The results given in Table 5 show that all variables are non-stationary at their levels but stationary at their first difference. These findings indicate that all considered variables for the five countries are integrated with order first I (1).

Table 5: Unit Root Test

Variable	CIPS-test		CADF-test	
	I (0)	**1(1)**	**I (0)**	**1(1)**
ln CO2	0.87	-3.19**	-1.52	-3.91*
ln GDP	1.82	-2.24**	-1.76	-3.56*
ln GDPS	1.46	-3.30**	-1.46	-3.33*
ln AGNG	9.20	-2.64**	-2.79**	-3.23*
ln RE	1.69	-5.69*	-1.43	-2.58**
ln TRDO	1.79	-6.65*	2.58**	-4.39*
ln UNR	-0.27	-6.58*	-0.40	-3.00*

*Significant at 1 percent, ** Significant at 5 percent

4.4 Cointegration Test

Cointegration tests are applied to panel data to see the long-run relationships between the variables in panel analysis. The stationarity of the time series variables at the first difference is the prerequisite for applying the cointegration test (Charfeddine & Mrabet, 2017). Co-integration tests are based on residual, likelihood, and error correction methodologies. In this study, we utilize Pedroni's cointegration residual-based test to check cointegration among the variables (Pedroni, 1999). This test has more explanatory powers than any other residuals-based panel cointegration tests. Table 6 represents the results of the Pedroni cointegration test. Six statistics out of eleven rejected the null hypothesis of no cointegration. The empirical results confirmed a long-term relationship between CO_2, real GDP in level and quadratic form, population aging, renewable energy use, trade openness, and unemployment rate.

Table 5: Pedroni Cointegration Test

	Statistic	**Prob**
Panel v-Statistic	-0.72	0.76
rho-Statistic	0.77	0.78
PP-Statistic	-4.28*	0.00
ADF-Statistic	-4.19*	0.00
Group wise rho-Statistic	1.85	0.97
PP-Statistic	-6.83*	0.00
ADF-Statistic	-4.84*	0.00

Note: * represents Rejection of H0 at a 1% significance level. Pedroni results are obtained through Eiews-10 with intercept and trend options. Automatic time length selection is based on SIC with lag value 1and Bartlett kernel was used with Newey-west automatic bandwidth selection.

4.5 Long Run Results

After validating cointegration among variables, the next step is to estimate the long-run relationship between variables. In the presence of endogeneity and cross-sectional dependencies, the OLS estimator provides biased and inconsistent results. For this, we utilized fully modified ordinary least squares (FMOLS) proposed by (Pedroni, 1999) to measure the long-run association as a primary estimation technique which is a suitable estimation technique in the presence of CSD and slope heterogeneity (Doğan et al., 2022). Zakari et al. (2022) believed FMOLS is good for small samples. It also solves endogeneity in the panel data set (Phillips & Hansen, 1990).

For co-integrated data, another widely used estimation technique is dynamic ordinary least squares (DOLS). It is a parametric approach and this study utilized DOLS as an alternative estimation technique. We used both parametric (DOLS) and semi-parametric (FMOLS) approaches in our study to get robust and consistent results.

Table 6 reports the estimated coefficients, their standard error, t-statistic, and p-value obtained from FMOLS. The results obtained from the FMOLS method show that all three variables, population aging, GDP per capita, and trade openness, significantly affect carbon dioxide emissions. GDP is a dominant factor of carbon emission in the model. Statistically, a 1% increase in GDP brings a 5.14% rise in carbon emissions. Similarly, a 1% increase in population aging, the second most important determinant, increases carbon emissions by an average of 1.25%. In comparison, a 1% increase in trade openness leads to an increase in carbon emissions of 0.19%. While renewable energy is the most vital factor in reducing carbon emissions and improving environmental quality. Each one percent change in renewable energy will decrease carbon emissions by, on average, 0.15 percent. Similarly, a one percent change in the unemployment rate reduces carbon emissions by 0.072 units on average. The long-run elasticity estimate of FMOLS also confirms the economic Kuznets curve hypothesis in these selected countries of South Asia. The sign of the slope coefficient of GDP square is negative; it means the GDP square term will contribute significantly towards the reduction in carbon emissions in the long run when the level of income surpasses a specific threshold level.

On the other hand, the results of the DOLS regression given in the second part of Table 6 show that population aging, GDP, and trade openness are statistically significant and positively affect carbon emissions. It means a 1% increase in population aging stimulates carbon emissions by 0.305%. Similarly, a 1% increase in GDP will increase carbon emissions by 9.37 %, and a 1 % increase in trade openness will increase carbon emissions on average by 0.22 %. In contrast, renewable energy and the unemployment rate significantly decrease carbon emissions. Renewable energy is a dominant factor in improving the environment, as a 1 % increase in renewable energy will decrease carbon emissions by 2.25 percent on average. Similarly, a 1 % increase in unemployment will decrease carbon emissions by 0.0689 percent. Unemployment is significant but its impact is low as compared to other factors. The existence of EKC is also confirmed in the DOLS model. These two different estimation techniques provide similar results. The nature and significance of the results in both models stay intact.

Table 6: The Long-run Estimates (Dependent Variable - carbon emissions per capita)

	FMOLS			**DOLS**		
Variable	Coefficient Value	Standard Deviation	Probability Value	Coefficient Value	Standard Deviation	Probability Value
ln AGNG	1.25*	0.01	0.00	0.03**	0.06	0.02
ln GDP	5.15 *	0.06	0.00	9.37 *	0.25	0.00
ln GDPS	-0.21 *	0.02	0.00	-0.67 *	0.02	0.00
ln RE	-0.15**	0.04	0.01	-2.25**	0.05	0.00
ln UR	-0.72**	0.03	0.02	-0.07**	0.02	0.05
ln TRDO	0.20*	0.04	0.00	0.22**	0.02	0.02
Cons	-0.228	2.90	0.94	-2.472**	1.200	0.03

Note: * significant at 1% significance level. **: significant at 5% significance level. For FMOLS, we used a weighted estimation method and a constant deterministic trend. Moreover, the estimator of the long-run covariance obtained with the Daniell kernel is the Newey-West fixed bandwidth. We also used a weighted estimation method for DOLS with a constant deterministic trend with (lead=1, lag=1). The estimator of the long-run covariance is used to compute the long-run variance weights with lags 7 using the Bartlett kernel, the Newey-West fixed bandwidth.

The evidence of the EKC hypothesis in South Asia is well explained. The growth and trade policies in South Asia are income-oriented not environment-friendly. These countries are focusing on GDP growth for sustainable development. Growth in South Asian countries remained at 7.8 percent in 2021, which is higher than in other regions where economies were recovering from the shock of COVID-19. For economic expansion South Asian countries heavily rely on nonrenewable energy resources (Shahbaz et al., 2015). The validation of EKC is like the findings of (Ahmad et al., 2017; Ahmad et al., 2013; Khan et al., 2022) which validates EKC in the light of energy consumption, population growth, and trade openness. These results are also similar to the findings of other regions (Fan et al., 2020; Kim et al., 2020). Second, the negative relationship between income and carbon emissions happens when income rises, the nations will be able to spend more on education, technological innovation, and research and development. As technological innovation and human skills increase, nations shift their industries from fossil fuels to renewable energy (Balsalobre-Lorente et al., 2022). South Asian countries are working under the first stage of growth and shortly when income increases, it is believed energy transition and technological spillover will take place and environmental quality will improve.

Population aging in South Asia is increasing and deteriorating environmental quality. Evidence exists that shows population aging increases energy demand while staying at home and aggravates carbon emissions. Poor health and less active lifestyles are also another reason for this positive association (Bardazzi & Pazienza, 2017; Yu et al., 2018). Another reason is South Asia's weather conditions, which are challenging both in summer and winter. Older adults in South Asia tend to secure physical comfort at home in summer and winter, increasing energy consumption (Abbas et al.,2023). Similar results showed that people over 65 are responsible for increasing CO2 emissions in India (Mehmood & Tariq, 2021). Thirdly, the South Asian region provides more government jobs than other developed nations. After retiring at 60, people receive handsome amounts and consume more as mentioned by (Zheng et al., 2022) the consumption behavior of Australian and USA citizens is the primary source of carbon emissions. They consume more food and energy as they spend more time alone in a large house.

Renewable energy reduces carbon emissions in South Asia. After the Paris Agreement, the use of renewable energy in South Asia is increasing particularly in India and Bangladesh. Although the pace of renewable energy in South Asia is slow due to the lack of financial support and infrastructure. However, continuing to improve technological innovation will reduce the costs of renewable energy and encourage nations to adopt it. Many other studies found renewable energy reduces carbon emissions (Ahmad et al., 2017; Vo, 2021). Renewable energy comes through sunlight, wind, rain, nuclear, and geothermal sources, decreasing fossil fuel-based energy consumption and improving environmental quality

(Leitão et al., 2021). Our results are similar to the findings of (Pata, 2021) that RE decreases carbon emissions.

The negative association between the unemployment rate and carbon emissions observed in this study confirms the environmental Phillips curve hypothesis in South Asia. Unemployment in South Asia is high, it reduces carbon emissions because due to unemployment natural resources are utilized less. When resources are not fully utilized then economic growth will be low and low will be energy consumption. In contrast relationship between employment, economic growth, and energy consumption increases carbon emissions has been observed in South Eastern European nations (Mitić et al., 2023). Trade openness increases carbon emissions in South Asia because the share of manufacturing and agricultural products in total trade is higher than services sectors. These products are fossil fuel intensive. These long-run results are like the other studies (Ahmed et al., 2017; Shahbaz et al., 2017).

5. Conclusion

This study empirically evaluates the effects of population aging, GDP, and unemployment on carbon emissions along with trade openness and renewable energy consumption for selected five South Asian countries by using panel data from 1996 to 2020. First, we examine the issue of cross-sectional dependency and slope heterogeneity to evaluate this association among these variables. And the stationarity of the variables with the help of cross-sectional dependency tests, Pesaran and Yagamata slope heterogeneity tests, generations CIPS, and CADF unit root tests. For long-run estimation, co-integration among the desired variables is found by applying Pedroni cointegration tests. We applied FMOLS and DOLS estimates to obtain results. The study results revealed that population aging, GDP, and trade openness increase carbon emissions, while unemployment and renewable energy decrease carbon emissions. The study's empirical results also confirm the existence of the EKC and EPC hypotheses in South Asia. Although our study provides valuable results, they are still not free from limitations. We used macro-level data for empirical analysis. In the future, using microdata will be beneficial in understanding the effects of population aging and unemployment on the environment. The EKC hypothesis can be better analyzed with the help of the threshold model in future research along with other macroeconomic factors related to population density, foreign direct investment, and energy political stability. Moreover, future research may consider ecological footprint, carbon footprint, and PM 2.5 as alternative indicators for environmental degradation while evaluating the effects of population aging, unemployment, renewable energy, and trade openness on carbon emissions.

We recommend the following policy suggestions based on our study's findings to reduce carbon emissions in South Asia.

1) The share of population aging is increasing in South Asia, particularly in India, Bangladesh, and Pakistan, hurting the environmental quality. Reducing older people's health problems associated with air pollution and other environmental changes needs to be addressed urgently. To reduce consumption, the governments of these nations should extend retirement age and introduce attractive savings schemes for older people.
2) Economic growth has deteriorated the environmental quality in South Asia. For future sustainable economic growth, three options are available: first, increase the use of alternative energy resources. Second, modernize the existing manufacturing structure; and third, bring sophistication to the exported basket of goods. To achieve this, technical and financial support from developed nations can play a vital role.
3) South Asia is a developing region with a higher level of unemployment and poverty. In the future, when economies grow, governments of these nations will have to provide more jobs, and there is a risk of more carbon emissions. To avoid this problem, the private and public investment in energy transition particularly the use of renewable energy at the domestic and industrial levels in South Asia need to be enhanced. The renewable energy sector is not only beneficial for sustainable economic growth but also has the potential to provide millions of jobs in the region. By doing this, South Asian unemployment can be reduced without environmental loss.

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