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RESEARCH ARTICLE

Does globalization affect the green economy and environment? The relationship between energy consumption, carbon dioxide emissions, and economic growth

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Abstract
This study analyzes the relationship between globalization, energy consumption, and economic growth among selected South Asian countries to promote the green economy and environment. This study also finds causal association between energy growth and nexus of CO_2 emissions and employed the premises of the EKC framework. The study used annual time series analysis, starting from 1985 to 2019. The data set has been collected from the World Development Indicator (WDI). The result of a fully modified ordinary least square (FMOLS) method describes a significantly worse quality environment in the South Asian region. The individual country as Bangladesh shows a positively significant impact on the CO_2 emissions and destroys the level of environment regarding non-renewable energy and globalization index. However, negative and positive growth levels (GDP) and square of GDP confirm the EKC hypothesis in this region. This study has identified the causality between GDP growth and carbon emission and found bidirectional causality between economic growth and energy use.

Keywords Globalization · Energy consumption · CO_2 emissions · Green economy · South Asian countries

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Introduction

The economy's growth (GDP) is highly connected with energy use and is taken as a measure for the "oxygen" for the whole world's countries. Non-renewable energy is a prerequisite for the achievement of economic growth. These countries are trying to achieve economic growth through industrialization, globalization, and trade liberalization. The quality of the environment can be strengthened by the effective use of energy and sustainable development policies of growth. More effective policies are required, especially in Asian countries where emissions remain high. Similarly, nitrogen and sulfur dioxide have been examined (Apergis and Ozturk 2015; Wang et al. 2016; Hanif and Gago-de-Santos 2016); others have also observed sulfur dioxide (Selden and Song 1994).

Global warming and environmental degradation have lately been a major challenge for the nations of the world. Increasing CO_2 emissions and other greenhouse gas (GHG) emissions have produced extensive environmental effects. These effects have created unexpected changes in weather conditions, increased earth temperatures, and presented more significant dangers to ecosystems. The answers to some questions can be obtained from the EKC model, such as whether an economy can achieve economic growth without worsening the ecological system and whether the environmental quality is deteriorating by the rapid economic growth. Prior empirical and theoretical studies have discussed the energy-growth-emission nexus in well-intentioned works; however, more research is required on this topic for further policy recommendations due to inconclusive findings. Additionally, climate change and global warming represent preeminent global issues. Sea levels are rising, snow and ice are melting in polar zones, and due to global warming, the average temperature of the earth is increasing. Notably, more significant government efforts can be reduced poverty and environmental degradation, and in these economies, the issue is to achieve sustainable economic growth.

Energy demand is essential for growth, but the supply side is limited (the supply of conventional oil and gas is predicted to decline) (Zaleski 2001). Nevertheless, geopolitical, economic, environmental, and technological challenges are confronted by the energy sector. Thus, energy is vital and increases environmental degradation in economic growth. The next century will face many energy challenges. Among these, energy demand and environmental degradation will be the largest issues due to rapid economic growth and dependence on energy sources. CO_2 emissions and climate change are becoming more prevalent due to fuel combustion (IEA 2015). Energy is essential for industrial and agricultural production, and this energy increases CO_2, nitrous oxide, and methane emissions. As a primary energy source worldwide, the fossil energy ratio is rising as fossil fuels produced 82 percent of the global energy in 2015. This ratio has remained roughly the same for the last 40 years, as reported by the IEA (IEA 2015). Renewable energy sources represent alternatives of non-renewable sources and can be helpful in overcoming these issues (Stern 2004).

Finally, following the global agenda for reducing CO_2 emissions, this study investigated the GDP growth and CO_2 emission relationship to determine the nexus between CO_2 emissions and growth, as well as to provide suggestions for further policymaking. The adoption of weak econometrics techniques, wrong statistical data, ignoring diagnostic testing or neglecting random walk trends, and serial dependence in time series analysis can be observed in testing the EKC hypothesis. The results maybe spurious if incorrect statistical techniques are applied. To overcome these issues, this study uses an overview of the cross-country panel time series to test the interim and long-term associations under the EKC scheme between the study variables. As an alternative, this study also used renewable energy and technological innovation impacts on environmental quality to obtain the most robust results. Therefore, this study examines the globalization and growth-emission nexus with other selected variables due to its importance in policymaking and sustainable economic growth across the globe. The main objective of this study is to identify the role of globalization and economic growth, i.e., does economic growth significantly increase/decrease CO_2 emissions in South Asian countries?

Literature review

Numerous researchers have found the links between CO_2 pollution, economic development, and energy sources as significant. Even though environmental pollution caused by energy and growth are especially important in Asian countries, however few researchers have analyzed the topic as a group for the South Asia region. In the context of the South Asian countries, this subject is also not well documented. Thus, this research includes existing studies on countries in South Asia. As a subsample, there have been some important past research, including in Asia-Pacific economies such as Karki et al. (2005); Lee and Oh (2006); Malla (2009); Narayan and Narayan (2010); Jaunky (2011); Niu et al. (2011); Zeshan and Ahmed (2013); Arif et al. (2020); Shabbir et al. (2020); Apergis and Ozturk (2015); Keho (2017); Le and Quah (2017); Liu et al. (2017); and Nasreen et al. (2017). Through the use of these possible variables within the EKC system, the contribution of this analysis is special, which makes this research distinct from other studies, and helps fill a literature void. Furthermore, this research includes the structure of energy use (non-renewable and renewable energy), technological innovation based on CO_2 mitigation, the financial growth role, and trade openness under the umbrella of the EKC framework.

The EKC framework is discussed by Yikun et al. (2021), Li et al. (2021), and evaluated the effects of economic growth on environmental quality. Subsequently, Dinda (2004) and Stern (2004) discussed this EKC hypothesis in their empirical analysis. The empirical studies of Tugcu et al. (2012); Mensah (2014); Acaravci and Ozturk (2010); Apergis and Ozturk (2015); Al-Mulali et al. (2016); and Jebli et al. (2016) have included various additional explanatory variables in assessments of carbon emission-growth nexus. They found that economic growth activities can significantly increase the level of GHG emissions. Lise (2006) has also tested this hypothesis for Turkey and India and has not found any CO_2 emission-growth nexus. The empirical findings of Robalino-López et al. 2014, 2015) do not support Ecuador and Venezuela's EKC hypothesis.

Moreover, Shahbaz et al. (2013c) examined the EKC hypothesis over 1970–2010 for Turkey, and they also verified the EKC hypothesis: increases in the rate of globalization significantly decrease CO_2 emissions. Shahbaz et al. (2016) explored the intensity of energy, globalization, and carbon emissions nexus for the 19 African countries throughout 1971–2012. Their research supports the existence of the EKC hypothesis for Algeria, Congo Republic, Zambia, Cameroon, Morocco, and Tunisia. Additionally, the study by Shahbaz et al. (2017c) for the 25 developed countries examined the globalization-carbon emissions relationship during 1970–2014. The findings show that globalization is significantly increasing CO_2 emissions. This analysis utilizes these theoretical aspects and assesses economic growth, energy use, environmental pollution, globalization, and other variables under the EKC method scheme. This analysis used the most recent data (1972–2015) with the latest econometrics techniques, and to fill the previous literature gap, a robust model is used in the empirical literature. Thus various econometrics techniques such as heterogeneous co-integrated panels (with cross-sectional dependence tests), panel unit root tests, the panel co-integration test (the Kao and Fisher), the fully modified OLS (FMOLS) test, the test of Granger causality, and "the Innovative Accounting Approach" (VDM and IRF) are used in our analysis. Additionally, the results for selected South Asian economies from 1972 to 2017 showed the long-run association between CO_2 emissions, growth, energy, and globalization under EKC's framework.

Methodology

This paper examined the fuel consumption and growth-led CO_2 emission concerning the EKC hypothesis. Using data from 1985 to 2019 for selected South Asian countries such as Bangladesh, India, Maldives, Pakistan, and Sri Lanka, this paper used the World Development Indicator (WDI) data to implement the panel time series analysis (Table 1).

Theoretical framework and hypothesis

This study tries to identify the effects of globalization, energy growth, and technological change in South Asian countries and the extent to which the sustainable environmental agenda influences this causal relationship. It is observed that due to technological advancements and modern usage, the consumption of energy increases globally and emissions of GHG under the scheme of the EKC hypothesis. Furthermore, this analysis comprises and tests on below two hypotheses.

> Hypothesis 1: There is an inverted U-shaped environmental Kuznets curve (EKC) association between CO_2 emissions and GDP growth for the selected South Asian countries.

> Hypothesis 2: It is expected that globalization can be harmful to the country's economic growth, which could be a sustainable pollution haven hypothesis across the countries.

The environmental degradation-growth nexus can be described in the EKC hypothesis (with an inverted U shape). Grossman and Krueger (1991) followed up on the work of Kuznets and described the environmental quality-growth nexus in three stages. The author discussed environmental degradation issues due to natural resource depletion. Environmental quality has been significantly reduced by countries attempting to achieve the highest economic growth in this first stage. Beyond this initial stage, the economies' main goal is to attain sustainable economic growth and welfare of the economy with technological innovation (clean environmental-based technologies) and to develop environmental policies to mitigate CO_2 emissions. Thus, economies (after reaching the highest level of income per capita) wish to move from poor environmental conditions to a clean environment for sustainable economic growth (Panayotou 1993). The analysis of EKC hypotheses regarding incomes, pollution, and other essential variables in a GDP square function has been used by various policymakers and researchers in the area of environmental economics.

To analyze the growth-environmental pollution nexus, this study applied EKC's theoretical framework in Eq. 1 (Grossman and Krueger 1991). The theoretical framework of the EKC framework is used in the following econometric model:

$$CO_{2it} = \alpha 1 + \alpha 2 Y_{it} + \alpha 3 \left(Y_{it}\right) 2 + \alpha 4 X_{it} + \mu_{it} \quad (1)$$

Table 1 Summary of data description

Variables	Description	Source
CO_2	Carbon emissions (in per capita of metric tons)	World Development Indicator (WDI) (2018)
GDP	GDP per capita (US$ with the base year of 2010)	World Development Indicator (WDI) (2018)
NRENW	Non-renewable energy consumption % of total final energy consume.	World Development Indicator (WDI) (2018)
GLOB	The KOF index of globalization	KOF Globalization (2019)

This study has included a few supplementary variables and economic growth nexus under the premises of the EKC hypothesis. Where CO_{2it} shows the carbon emission (per capita) level (environmental pollution), Y_{it} shows GDP (per capita) income (economic growth), and other influential macroeconomic variables are indicated by X_{it}. To make the model consistent and efficient with a meaningful interpretation, we have thus (the natural log is used for Eq. (1)):

$$\mathrm{InCO}_{2\mathrm{it}} = \alpha_0 + \alpha_1 \mathrm{InGDP}_{\mathrm{it}} + \alpha_2 \left(\mathrm{InGDP}_{\mathrm{it}}\right)^2 + \alpha_3 \mathrm{InGDP}_{\mathrm{it}} + \mathrm{e}_{\mathrm{it}} \tag{2}$$

The influence of non-renewable energy sources, GDP growth, and globalization on CO_2 emissions in the selected South Asian countries through 1972–2017 are mentioned in Eq. (3) and can be written as follows:

$$\mathrm{InCO}_{2\mathrm{it}} = \alpha_1 + \alpha_2 \mathrm{InGDP}_{\mathrm{it}} + \alpha_3 \left(\mathrm{InGDP}_{2\mathrm{it}}\right) + \alpha_4 \mathrm{InNREW}_{\mathrm{it}} + \alpha_5 \mathrm{InGLOB}_{\mathrm{it}} + \mathrm{e}_{\mathrm{it}} \tag{3}$$

Before testing the co-integration method, it is necessary to identify the statistical properties of the model regarding stationary. In the model, it is essential to assess the unit root's presence due to dependent and independent variables with its long-run association. Thus, following the co-integration test, the order of integration may be the same for all the employed variables. Thus, various unit root tests have been designed in this study (Dickey and Fuller 1981; Pesaran et al. 2001). For this purpose, the prerequisite in time series econometrics analysis is unit root test (Ozturk and Acaravci 2013).

This study used various unit root tests to control the problem of non-stationary data in the time series data. The regression results will be biased or may calculate a spurious regression if time series variables are not stationary. Maddala and Wu suggested that multiple unit root tests might be employed to control the problem of individual regression inaccuracies across the cross sections. This study finds no evidence regarding the presence of unit root in the panel data series after applying the cross-sectional independence test. The two essential subgroups of unit root analysis are divided into line with cross-sectional independence.

Homogenous (common unit root process) case

The panel Levin-Lin-Chu (LLC) is the more common test compared with the other two tests developed by Breitung (2000) and Hadri (2000). Identical or homogenous cross sections are the assumption of this group. The extension of the augmented Dickey-Fuller (ADF) approach is the LLC test; the assumption of homogeneity (in cross-sectional independence) is incorporated in the autoregressive coefficients under the test of ADF. Bildirici and Kayikçi proposed that this non-stationary test is comparatively superior to common panel unit root tests.

Heterogeneous case

Homogeneity in panel data analysis is a very restrictive assumption, and the dynamic properties of the same variable for all series are difficult to calculate; following the assumption of homogeneity can guide to spurious findings. Thus, based on Maddala and Wu (1999), additional alternative (two) tests are used by many researchers, namely the approaches of Fisher-ADF and Fisher-PP (Philips-Perron). In order to permit heterogeneity across the panel, this study uses another alternative test, namely Im et al. (2003) have designed the test of IPS. This study identifies the problem of cross-sectional dependence; four significant CD tests for robustness are employed. The study applied the Pesaran et al. (2001), Baltagi et al. (divided by LM test), and then finally the Pesaran et al. (2001) test of CD. The findings of the CSD test are presented in Table 3. Besides, the findings of the panel unit root were reported in Table 4.

This study used the non-parametric approach designed by Pedroni (2004) in the model to overcome the endogeneity and serial correlation problem. The severe issues of autocorrelation and endogeneity (which can generate nuisance problems and bias the results of coefficient estimates from panel data regression) may have arisen in the panel least square regression; therefore, this study used the FMOLS approach to identify the long-run parameter estimates. Granger causality is used to identify the causal correlation between the dependent variable and the explanatory variables with its lagged values.

This study used the panel Dumitrescu and Hurlin (2012) causality test. Based on the Innovation Accounting Approach (IAA), the next step consists of two methods, including the "variance decomposition method" (VDM) and the "impulse response function" (IRF). This empirical analysis accounts for these sequential steps to provide robust statistical inferences, and these findings will offer appropriate suggestions to policymakers in a given set of economies.

Data description

This paper examined the energy use and growth that led to CO_2 emission nexus under the EKC hypothesis in selected South Asian countries such as Bangladesh, India, Pakistan, Maldives, and Sir Lanka through 1985 to 2019. This paper used CO_2 emission as a proxy of environmental degradation. Besides, energy per capita is used to measure non-renewable energy, while the EKC hypothesis is the measure of the square term of GDP. Similarly, the energy consumption (i.e., non-renewable) proxy is used to measure the percentage of total final energy consumption. Next, to measure globalization's impact on environmental degradation, the globalization index is an important explanatory variable. Furthermore, social globalization index amalgamation and economic and political globalization index are employed for the globalization index. This paper follows the preceding subsequent values to fill the data gaps for the model's mentioned variables (Table 2).

Empirical results and discussion

The statistical results of descriptive statistics for the explanatory variables.

Table 2 Summary of descriptive statistics

Description	$LnCO_2$	LnGDP	Ln GDP2	LnNREW	LnGLOB
Mean	9.757	6.141	12.282	3.793	3.444
Median	9.784	6.055	12.110	3.844	3.447
Maximum	11.200	6.826	13.653	4.300	3.955
Minimum	8.163	5.761	11.522	3.030	2.897
Sd. dev.	0.891	0.299	0.598	0.392	0.331
Skewness	−0.096	0.796	0.796	−0.456	−0.043
Kurtosis	1.887	2.515	2.515	1.925	1.811
Jarque-Bera	2.390	5.203	5.203	3.727	2.661
Probability	0.302	0.074	0.074	0.155	0.264
Sum	439.097	276.366	552.732	170.729	155.003
Sum sq. dev.	34.938	3.944	15.777	6.779	4.841

The statistical findings of cross-sectional dependence (CSD) are reported in Table 3. To find CSD's presence between the panel data, we have used four tests: Pearson LM normal, Pearson CD normal, Breusch-Pagan chi-square, and Friedman chi-square. The findings of CSD show that in a panel data analysis, the cross-sectional dependency found between the data and significance of p values rejected the null hypothesis. The acceptance of the alternative hypotheses verified the cross-sectional reliance among these South Asian countries.

Table 4 reports the unit root result by using the tests of Pesaran and Shin, Breitung (2000), and Hadri (2000), respectively. The cross-sectional dependence test can be used to detect the heterogeneity in the panel model. Thus to control the heterogeneity across the panel model, this study used an alternative IPS test designed by Im et al. (2003). Table 4 reports the results of the Hadri (2000), Shabbir and Muhammad (2019), Breitung (2000), and Im et al. (2003) tests, as all variables are found stationary at the level in line with Hadri (2000) and Im et al. (2003), while some variables are not stationary at the level in line with Breitung (2000) test. Also, except for the Breitung (2000) test, all the variables are found stationary at the level in line with Im et al. (2003) and Hadri (2000) tests.

Different co-integration tests, i.e., Pedroni (2004) and Kao panel co-integration tests and FMOLS, are used in this study. The results of panel v-statistic, panel rho-statistic, panel Phillips–panel ADF-statistic and Perron (PP) (within dimension method) statistic are reported in Table 5. These co-integrated tests are based on "Engle and Granger (1987)," where different methods, namely group ADF-test, group PP-statistic, and group rho statistic, are also used in this analysis. All the variables are co-integrated according to the findings, and there is a long-term association among the variables. According to the results of the Kao t statistic, the long-term association was found among all these variables. There is a long-run nexus between CO_2 emissions, GDP growth, non-renewable energy, and globalization index in the selected South Asian countries. The studies of Zeshan and Ahmed (2013), Apergis and Ozturk (2015), and Ahmed et al. (2017a, 2017b) supported the results of this empirical analysis.

This study investigated growth-driven emissions for the South Asian countries under the scheme of the EKC hypothesis. This study's results fully support the inverted EKC hypothesis, and the findings of the study show that growth activities significantly increase GHG emissions. The findings of various previous empirical studies have provided consistent results for the framework of the EKC hypothesis (Keho 2017; Shabbir et al. 2020; Nassani et al. 2017; and Rahman 2020, Yu et al. 2020, Shabbir 2017, and Shahbaz et al. 2017a, 2017bndings could not support more for the EKC hypothesis regarding environmental pollution-growth nexus. Ang (2007)

Table 3 The results of the residual cross-sectional dependence test

Test	Statistic	Prob.	Null hypotheses	Result
Breusch-Pagan chi-square	7.245	1	No cross-sectional dependence (CSD) in residuals	Reject
Pearson LM normal	1.039	1.08	No cross-sectional dependence (CSD) in residuals	Reject
Pearson CD normal	−0.281	0.99	No cross-sectional dependence (CSD) in residuals	Reject
Friedman chi-square	23.895	0.78	No cross-sectional dependence (CSD) in residuals	Reject

and Iwata et al. (2010) have tested this hypothesis and confirmed the EKC's existence for China and France. Various prior studies of Copel and Taylor (2004); Halicioglu (2009, b); Anser et al. (2021); and Jalil and Mahmud (2009) have also used economic growth and environment with trade to identify the EKC hypothesis. The empirical results of Jalil and Mahmud (2009) and Ang (2008) show that trade significantly increases CO_2 emissions for China, Turkey, and Malaysia. The empirical analyses of Shahbaz et al. (2013a, b, c) and Uddin et al. (2017) for Indonesia and Sri Lanka, respectively, indicate that economic growth is significantly increasing the level of CO_2 emissions by energy consumption. The CO_2 emissions-growth relationship fully supported the EKC (inverted U-shaped) in all of the studies mentioned above. An inverted U-shaped EKC curve was found in the context of short- and long-term analyses. Consequently, it is concluded that the discussions on energy and growth have driven CO_2 emission nexus supporting the positive connection between environmental quality and the use of energy for South Asian countries.

The nexus between CO_2 emissions and its three essential components, energy use, globalization, and economic growth, are used in this study. Thus Kao, Pedroni co-integration, and FMOLS tests were used to identify the associations among these variables. Moreover, these findings showed that GDP growth, non-renewable energy, and globalization index significantly influence the CO_2 emissions in the South Asian regions. Table 6 and Table 7 have reported the results of full and country-specific FMOLS, respectively. The full panel of FMOLS findings in Table 7 indicates that these variables significantly increase South Asian regions' environmental degradation. Furthermore, these economies' empirical results suggest that fossil fuel is substantially increasing the CO_2 emissions in this region. Thus, full FMOLS results show that if there is a unit change in non-renewable energy, it will lead to a 0.84 unit change in CO_2 emissions holding all other variables being constant. The findings of Liu et al. (2007), Soytas and Sari (2009), Tao et al. (2008), Saboori and Sulaiman (2013a, b), Ahmed et al. (2017a, b), and Nasreen et al. (2017) supported the results of this study. Furthermore, all these five economies are predominantly involved in emissions-intensive energy consumption, and increased future demand and environmental degradation are anticipated for these economies.

Jalil and Mahmud (2009), Narayan and Narayan (2010), and Jaunky (2011) discussed the energy pollution and economic growth (under EKC) nexus besides Soytas et al. (2007), Ang (2007, 2008), Shabbir and Wisdom (2020), Apergis and Payne (2009), Sadorsky (2010); and similarly

Table 4 Panel unit root test analysis

	Breitung test		Im-Pesaran-Shin (IPS) test		Hadri test	
Variables	*t* values	*p* values	*t* values	*p* values	*t* values	*p* values
$lnCO_{2it}$	−1.078	0.4130	−1.875	0.0060***	−2.606	0.0040***
$lnGDP_{it}$	−19.949	0.01200***	−2.889	0.0050***	−3.037	0.0000***
$ln(GDP_{it})2$	−35.587	0.0000***	−2.909	0.0030***	−3.406	0.0030***
$lnNRENW_{it}$	16.742	0.0010***	−4.293	0.0020***	−2.979	0.0010***
$lnGLOB_{it}$	−0.868	2.8010	−4.038	0.0020***	−4.62	0.0000***

*** and ** signify 1 and 5% levels of significance

Table 5 The statistical results of the Pedroni and Kao co-integration

Pedroni (1999, Pedroni 2004) residual co-integration test		
Within dimension		
	Statistic	Prob.
Panel v-statistic	−0.5301	0.7020
Panel rho-statistic	−2.8286	0.0023***
Panel PP-statistic	−4.2235	0***
Panel ADF-statistic	0.0413	0.5165
Between the dimension		
	Statistic	Prob.
Group rho-statistic	−1.0664	0.1431
Group PP-statistic	−5.5722	0.000***
Group ADF-statistic	−2.1206	0.017***
Kao (1999) panel co-integration test		
ADF	*t* statistics	*p* value
	22.07927	0.0000

SIC is used to select the lag length criteria. *** and ** signify 1 and 5% levels of significance, respectively

Table 6 The statistical findings of FMOLS technique (country-specific long-run elasticities)

Country name	Variables	Coefficient	*t* statistics	Prob
Bangladesh				
	$lnGDP_{it}$	4.63	2.01	0.05
	$ln(GDP_{it})2$	−0.30	−1.73	0.09
	$lnNRENW_{it}$	0.89	7.03	0.00
	$lnGLOB_{it}$	0.88	4.52	0.00
India				
	$lnGDP_{it}$	1.62	13.01	0.00
	$ln(GDP_{it})2$	−0.06	−18.38	0.00
	$lnNRENW_{it}$	1.53	15.80	0.00
	$lnGLOB_{it}$	0.87	5.13	0.00
Maldives				
	$lnGDP_{it}$	15.81	237.88	0.00
	$ln(GDP_{it})2$	−1.08	−19.58	0.00
	$lnNRENW_{it}$	0.63	4.43	0.00
	$lnGLOB_{it}$	0.39	2.38	0.02
Pakistan				
	$lnGDP_{it}$	13.56	5.39	0.00
	$ln(GDP_{it})2$	−0.92	−4.83	0.00
	$lnNRENW_{it}$	0.47	2.37	0.02
	$lnGLOB_{it}$	1.11	7.27	0.00
Sri Lanka				
	$lnGDP_{it}$	2.50	2.10	0.04
	$ln(GDP_{it})2$	−0.12	−1.54	0.13
	$lnNRENW_{it}$	1.08	11.23	0.00
	$lnGLOB_{it}$	0.08	0.33	0.75

The turning point of EKC 6455.579 per capita US$

Where $=\alpha_2$ is natural log GDP_{it} and α_3 natural $log(GDP_{it})2$

Table 7 The statistical findings of FMOLS technique: full panel

Variables	Coefficient	*t* statistics	Prob
$lnGDP_{it}$	3.86	4.28	0.00
$ln(GDP_{it})2$	−0.22	−3.61	0.00
$lnNRENW_{it}$	0.84	8.07	0.00
$lnGLOB_{it}$	0.55	0.01	0.01

Le and Quah (2017) also discussed the nexus of energy sources, growth, and environmental quality. The positive (+) and negative (−) values of GDP and GDP^2, respectively, also support the EKC hypothesis in this region. Furthermore, a unit increase in GDP and globalization index increases the emissions level by 3.86 and 0.55, respectively. Similarly, a unit increase of GDP square significantly decreases the level of CO_2 emission by 0.22. These finds are endorsed by the findings of Ahmed et al. (2017b).

Additionally, the FMOLS results for the country specific shows that in Bangladesh, globalization index and non-renewable energy have a significantly positive impact on the GHGs and destroy the environment's level. Similarly, this study's findings support EKC's evidence because the GDP and GDP square values are positive and negative, respectively. Thus, the results of FMOLS show that if there is one unit change in non-renewable energy and globalization, it will lead to a total of 0.89 and 0.88, respectively, in the unit change in CO_2 emissions if all other variables are constant. The findings are supported by the results of Shahbaz et al. (2017a), Shahbaz et al. (2017b). Furthermore, results show that the level of CO_2 emission significantly increases by 4.63 if there is a 1% increase in the level of growth, and a 1% increase in GDP square substantially decreases the level of CO_2 emission by 0.30 if there is no change in other variables. For Bangladesh, the GDP growth is the most significant contributing variable in the destruction of the environment, whereas according to the results of FMOLS, India indicates the use of energy, globalization, and GDP growth rate significantly increases the level of CO_2 emissions.

The values of GDP and GDP^2 indicate both positive and negative to confirm the evidence of the EKC hypothesis. If there is a 1% increase in GDP, the level of CO_2 emission significantly increases by 1.62, and a 1% increase in GDP square substantially decreases the level of CO_2 emission by 0.06. Thus, FMOLS results show that if there is one unit change in non-renewable energy and globalization, it will lead to 1.53 and 0.87, respectively, unit change in CO_2 emissions if holding all other variables constant. In Maldives and Pakistan, the level of CO_2 emission significantly increases due to the GDP growth rate. The evidence of the EKC hypothesis was found in both countries. For Sri Lanka, the CO_2 emission is also enhanced by the GDP growth and energy consumption significantly which were found to be the most significant contributors of CO_2 emission in this country. Globalization is the smallest contributor to environmental degradation in the homeland of Sri Lanka. Thus results show that if there is one unit change in non-renewable energy and globalization, it will lead to 1.08 and 0.08, respectively, unit change in CO_2 emissions. Moreover, a 1% rise in GDP significantly worsens the environment quality (CO_2 emission) by 2.50, and a 1% rise in the level of GDP square substantially decreases the level of CO_2 emission by 0.12.

This study employed the Dumitrescu-Hurlin test (2012) to determine the causal relationship between energy, GDP, GDP square, and globalization. Table 8 reported the statistical results of the Dumitrescu-Hurlin test (Granger causality test). The bidirectional causality is moving from energy use to GDP. The uni-directional causality is running from CO_2 to GDP, GDP^2 to CO_2, GDP to globalization, GDP^2 to globalization, non-renewable energy to globalization, and non-renewable energy to GDP^2.

The findings of VDM are reported in Table 9 in the context of selected South Asian countries. The change in a variable due to its contribution through various exogenous variables and innovative shock can be accounted for by this method. Furthermore, regarding CO_2 emission between 1972 and 2015, the significant endogenous contribution of CO_2 is 49.73 percent due to innovative shock. These results reveal that in the Asian region, the (GDP_{it}) sources of energy and globalization were dominant elements for CO_2 emission. The findings of VDM are consistent with the regression analysis findings, and for the next 10 years, all these variables are included in the proposed framework. The graphical representation of the "impulse response function (IRF)" illustrated in Fig. 1 explains that when the shock is given to one variable, then the other factors respond. The lower and upper bound values can show the one standard deviation's values. The graphical analysis of the impulse reaction function represents the variable and their response, respectively. The reaction of CO_2 emission to energy consumption is positive, which shows that energy increases the level of environmental degradation. Globalization, growth, and CO_2 emission are positively related to each other in an increasing trend. The response of CO_2 emission to energy use is positive initially, reaching a steady state beyond the 9th period of the sample. The role of growth rate and the GDP square toward emission of CO_2 are positively reaching a constant state throughout the sample.

Comparative analysis of EKC results

This study try to examine the relationship between energy, environment, growth, and other variables under the premises

Table 8 Panel causality Dumitrescu-Hurlin test (full panel)

S. no.	Hypothesis	*W* stat	*Z* stat	Prob	Result	Conclusion
1	LCO_2 LGDP	2.560	1.560	0.249	No	
	LGDP LCO_2	4.576	3.576	0.040	Yes	Unidirectional causality
2	LCO_2 $LGDP^2$	1.906	0.907	0.497	No	
	$LGDP^2$ LCO_2	4.650	3.650	0.030	Yes	Unidirectional causality
3	LCO_2 LNRENW	1.098	0.098	0.359	No	
	LNRENW CO_2	6.143	5.143	0.000	Yes	Unidirectional causality
4	LCO_2 LGLB	1.574	0.574	0.380	No	
	LGLB LCO_2	2.816	1.816	0.080	Yes	Unidirectional causality
5	LGDP GDP^2	0.208	−0.739	0.477	No	
	$LGDP^2$ LGDP	0.262	−0.613	0.466	No	Neutrality
6	LGDP LRENW	4.951	3.951	0.041	Yes	
	LNRENW LGDP	11.823	10.824	0.000	Yes	Bidirectional causality
7	LGDP LGLB	3.753	2.753	0.005	Yes	
	LGLB GDP	1.689	0.689	0.560	No	Unidirectional causality
8	$LGDP^2$ LNRENW	2.199	1.199	0.230	No	
	LNRENW $LGDP^2$	11.767	10.767	0.000	Yes	Unidirectional causality
9	$LGDP^2$ LGLB	0.775	−0.224	0.822	No	
	LGLB $LGDP^2$	12.697	10.697	0.000	Yes	Unidirectional causality
10	LNRENW LGLB	1.912	0.912	0.456	No	
	LGLB LNRENW	6.383	5.383	0.000	Yes	Unidirectional causality

Table 9 The results of the variance error decomposition forecast model

Variance decomposition of CO_{2it}						
Period	SE	CO_{2it}	$NRENW_{it}$	GDP_{it}	$(GDP_{it})^2$	$GLOB_{it}$
1	0.053463	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.064543	79.09123	0.004104	0.015498	1.688469	19.20070
3	0.072142	66.04123	0.851420	0.246249	1.614706	31.24639
4	0.078430	62.30278	1.326685	0.703257	1.411935	34.25534
5	0.084180	59.37292	2.441953	0.824865	1.289188	36.07107
6	0.089467	56.56463	2.752867	0.941740	1.208907	38.53185
7	0.094385	54.16059	3.052759	0.971155	1.113945	40.70155
8	0.098988	52.41041	3.346803	0.992818	1.015428	42.23455
9	0.103322	50.97510	3.654140	0.995887	0.933091	43.44178
10	0.107395	49.73146	3.894635	0.986339	0.878239	44.509
Variance decomposition of $NRENW_{it}$						
Period	SE	CO_{2it}	$NRENW_{it}$	GDP_{it}	$(GDP_{it})^2$	$GLOB_{it}$
1	0.034535	31.87078	68.12922	0.000000	0.000000	0.000000
2	0.041244	36.66831	49.58632	0.969486	3.605675	9.170207
3	0.044430	33.72261	43.59082	0.907179	5.520787	16.25861
4	0.047971	34.41351	37.40430	2.211239	7.149582	18.82138
5	0.051180	33.83550	33.57368	2.392792	9.461705	20.73632
6	0.054482	33.04709	29.77826	2.822463	11.99424	22.35796
7	0.057849	31.94314	26.72074	3.050981	14.83178	23.45336
8	0.061297	30.88558	24.02483	3.319412	17.92518	23.84499
9	0.064986	29.65769	21.59964	3.583062	21.49490	23.66470
10	0.069006	28.19449	19.32307	3.846801	25.62172	23.01391
Variance decomposition of GDP_{it}						
Period	SE	CO_{2it}	$NRENW_{it}$	GDP_{it}	$(GDP_{it})^2$	$GLOB_{it}$
1	0.014070	10.00017	0.920363	99.07946	0.000000	0.000000
2	0.016145	20.07378	13.61939	75.39856	0.289688	3.618581
3	0.017505	20.76224	11.80742	65.29934	5.685593	10.44540
4	0.019871	30.90184	12.16973	51.21608	15.60387	15.10846
5	0.022793	30.72339	9.811252	39.18111	29.04921	16.23504
6	0.026456	40.20847	8.355201	29.65772	40.90296	15.87564
7	0.030838	40.48563	6.739829	22.57663	51.41638	14.78153
8	0.036092	30.75645	5.417601	17.34617	60.18060	13.29917
9	0.042379	30.04408	4.351367	13.57158	67.37784	11.65513
10	0.049879	30.41008	3.494791	10.85631	73.19366	10.04516
Variance decomposition of $(GDP)^2$						
Period	SE	CO_{2it}	$NRENW_{it}$	GDP_{it}	$(GDP_{it})^2$	$GLOB_{it}$
1	0.164948	0.007600	0.983546	98.95070	0.058150	0.000000
2	0.190252	7.389810	13.64122	74.52314	0.768169	3.677658
3	0.208039	6.820125	11.58595	63.30471	7.825880	10.46333
4	0.239443	5.732097	11.69370	48.42815	19.37892	14.76713
5	0.278498	5.342239	9.214914	36.13943	33.80341	15.50001
6	0.327042	4.713989	7.710922	26.87897	45.83009	14.86603
7	0.384881	3.961818	6.136183	20.24527	56.02468	13.63205
8	0.453880	3.253186	4.887105	15.50049	64.22880	12.13042
9	0.536104	2.594748	3.904165	12.16592	70.78248	10.55268
10	0.633860	2.027605	3.129035	9.816157	75.97134	9.055861

Table 9 (continued)

Variance decomposition of CO_{2it}						
Period	SE	CO_{2it}	$NRENW_{it}$	GDP_{it}	$(GDP_{it})2$	$GLOB_{it}$
Variance decomposition of $GLOB_{it}$						
Period	SE	CO_{2it}	$NRENW_{it}$	GDP_{it}	$(GDP_{it})2$	$GLOB_{it}$
1	0.033245	2.431226	5.949910	3.884664	5.465288	82.26891
2	0.038717	4.797875	4.388962	7.918514	4.715521	78.17913
3	0.042687	16.83483	5.322983	6.853499	4.650501	66.33819
4	0.044803	18.97840	7.591718	6.221787	4.221725	62.98638
5	0.046351	19.91540	7.133334	5.941443	3.995294	63.01453
6	0.047843	20.66431	7.016624	5.615584	3.802581	62.90090
7	0.049216	21.64652	6.943423	5.377727	3.620832	62.41149
8	0.050529	22.43852	6.956506	5.174904	3.467411	61.96266
9	0.051752	23.02819	6.923553	4.997245	3.332943	61.71807
10	0.052921	23.55079	6.892059	4.838889	3.204856	61.51341

of the EKC framework to evaluate an inverted U-shaped relationship between energy, growth, and globalization with CO_2 emissions in a panel of selected South Asian countries. Various econometrics techniques are used in this study such as heterogeneous co-integrated panels including unit root tests (panel), the Kao and Pedroni panel co-integration test, the test of fully modified OLS (FMOLS), and the Innovative Accounting Approach. This study also employed Dumitrescu-Hurlin test (2012) to find out the causal relationship between energy, GDP, GDP square, and globalization. The empirical studies of Velthuijsen and Worrell (2002), Ejaz et al. (2017), Saleem et al. (2019a, b), Liu et al. (2020), Tugcu et al. (2012), Mensah (2014), Nguyen et al. (2020), Apergis and Ozturk (2015), Al-Mulali et al. (2016), Muhammad et al. (2020), and Jebli et al. (2016) have included various additional explanatory variables in assessments of economic growth and GHG emissions under the premises of the EKC hypothesis.

The study based on the Innovation Accounting Approach (IAA), which consists of two methods including the “variance decomposition method” (VDM) and the “impulse response function” (IRF). The response of carbon emission to impulses of time series variables can be modeled by an “impulse response function” (IRF) model. The “impulse response function” (IRF) method is used to predict the interactions among all abovementioned variables over a period of time. In other words, the impulse response function is used to determine the associations among the study variables. If shocks are given to a specific variable, then the IRF technique shows the magnitude of the correlation between the selected variables beyond the specified time period, which identifies the response of one variable when a shock is given to another variable. Whereas, Yihdego and Webb (2010) used transfer function-noise (TFN) model for IRF, our study based on IRF based on IAA with graphical representation. Graphical illustration of our study based on IRF is revised, and interpretation of the results is according to IAA approach in detail.

Conclusion

This analysis utilizes these theoretical aspects and assesses economic growth, energy use, and globalization and affluence within the environmental Kuznets curve analysis framework. The long-run association between CO_2 emissions, real GDP growth, the square of GDP growth, energy sources, and globalization in selected South Asian economies from 1985 to 2019 was examined. Moreover, to detect the growth-environment association, the EKC frame was used. Various econometrics techniques are used in this study, such as heterogeneous co-integrated panels, also including unit root tests (panel); the Kao and Pedroni panel co-integration test; the test of fully modified OLS (FMOLS); the Dumitrescu-Hurlin test; and the Innovative Accounting Approach. The energy use is substantially increasing the CO_2 emissions resulting in GHG issues in this region. These South Asian countries are facing severe environmental degradation challenges. Moreover, these findings showed that GDP growth, non-renewable energy, and globalization index significantly influence the environment’s quality in the South Asian region. The overall statistical results from IRF indicate that growth, non-renewable energy consumption, and globalization vary if shock is given to the carbon emission variable. They also show that non-renewable energy use is the dominant resource in this region for GDP growth and found also that globalization spurs CO_{2it}

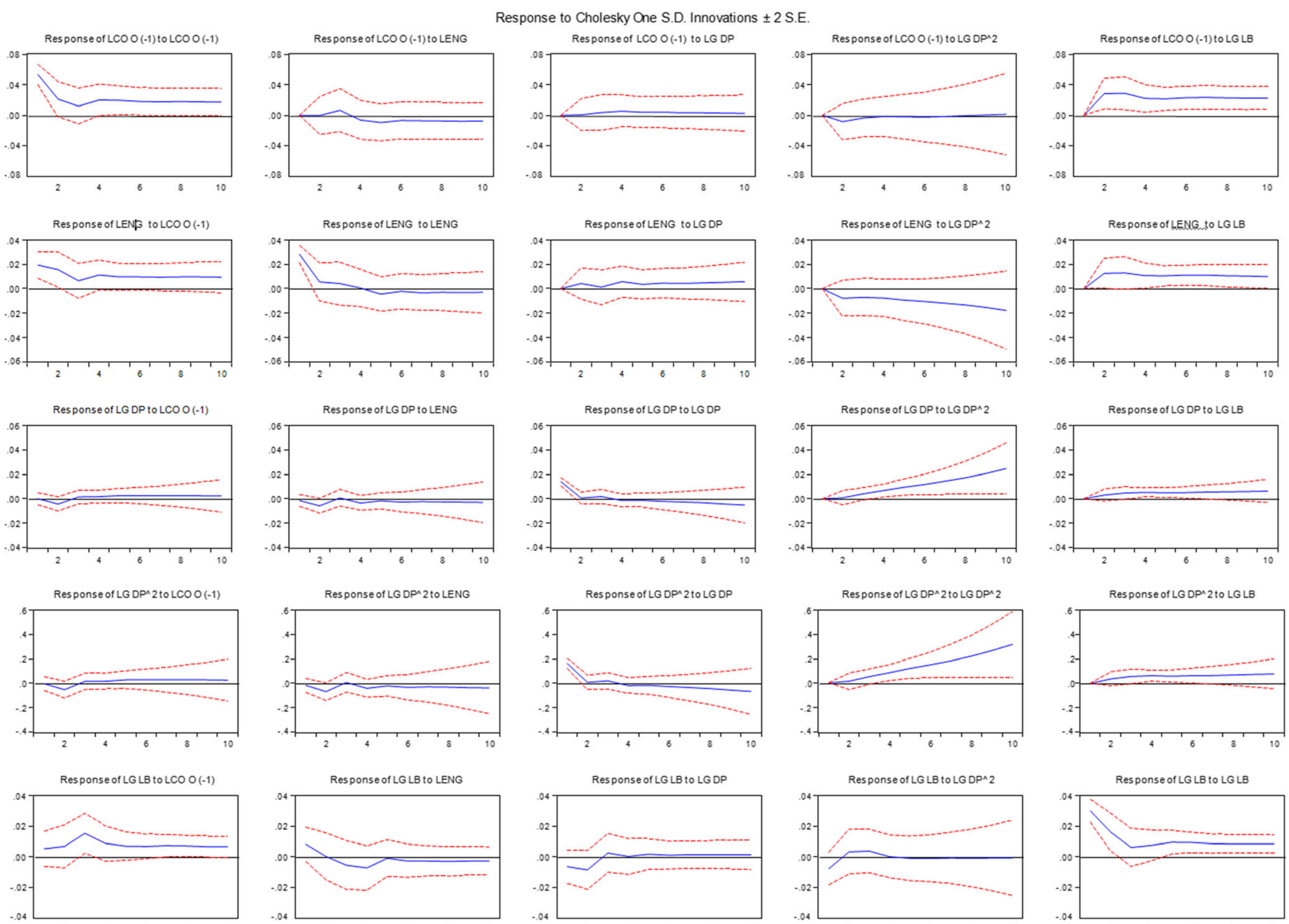
emission in this region. We used Innovation Accounting Approach (IAA), and impulse response function is part of the IAA.

The country-specific FMOLS test findings are also consistent with the full FMOLS results because in South Asian countries, the key determinants of CO_2 emission are GDP growth, energy consumption, and globalization. The study recommends policy implications in terms of vital initiatives to control CO_2 emissions and regional integration to control environmental degradation in this region. To improve environmental quality from an energy policy standpoint, policymakers should focus on clean energy policies. Improving energy efficiency, investing in renewable resources, boosting the utilization of cleaner energy sources, and decreasing energy intensity are the main options to mitigate carbon emission.

Appendix

Author contribution Dr Khalid has completed the data analysis part, Mr. Usman completed the “Introduction” section, Dr Danish completed the “Literature review” section, Mr Malik Shahzad wrote the “Methodology” section, Dr Sharif interpreted the data analysis section, Dr Tabash wrote the conclusion, and Miss Lydia Bares wrote abstract parts and format the paper as per journal requirements.

Fig. 1 Impulse response function



\raster(100%,p)=":1::\\10.82.5.6\springer\Prod\jwf\figures\HES\HES114243\s11356-021-14243-4Fmc1b.tif"

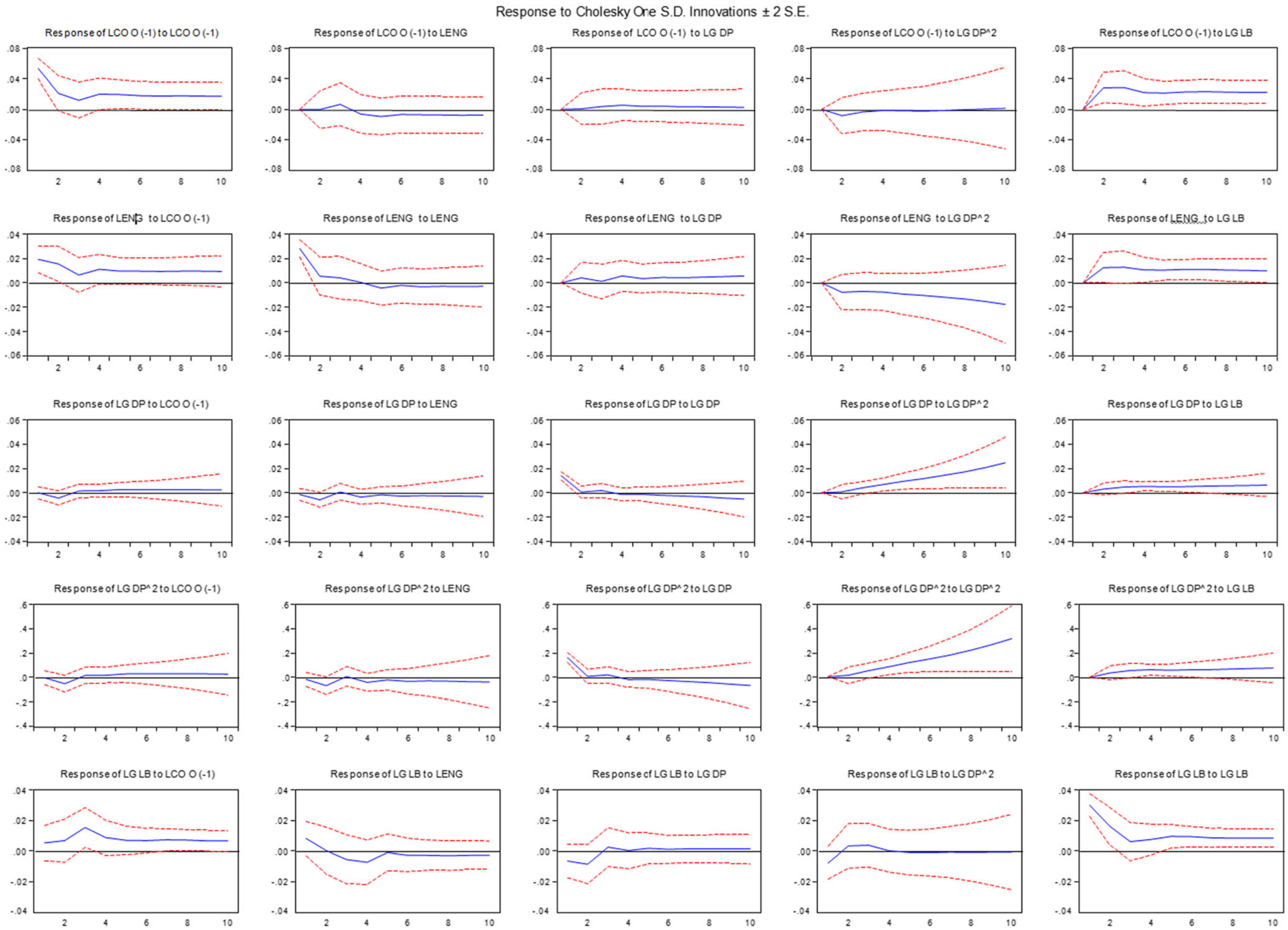


Fig. 1 continued.

Data Availability The data is available on request from corresponding author.

Declarations

Ethics approval and consent to participate This study didn't use any kind of human participants or human data, which require any kind of approval.

Consent for publication Our study didn't use any kind of individual data such as video and images.

Competing interests The authors declare no competing interests.

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