



Industrialization, energy consumption, and environmental pollution: evidence from South Asia

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Abstract

This study has been carried out to analyze the contribution of industrialization and energy consumption by keeping the role of urbanization on environmental pollution for South Asia. The study used Augmented Mean Group (AMG), Common Correlated Effects Mean Group (CCEMG) analysis, Westerlund co-integration test, and Dumitrescu-Hurlin causality test for the panel of South Asia covering the period 1984–2016. To measure the status of environmental pollution, CO₂ is taken as a proxy indicator, and industrialization is measured by the industrial value-added. The results of AMG demonstrate that industrialization and energy consumption are significant indicators of environmental pollution and these empirical findings are also confirmed by the CCEMG model. The long-run co-integration between industrialization, energy use, urbanization, capital, and environmental pollution is also confirmed by the Westerlund co-integration test. The findings of the Dumitrescu-Hurlin causality test also confirmed the bidirectional causality between industrialization and pollution. A unidirectional causality is observed from energy consumption to pollution. The study suggests formulating policies for energy-efficient technologies in the industrial sector and the high-speed pattern of urbanization.

Keywords Industry · Environment · Energy · South Asia

JEL Classification O14 · Q40 · Q53 · F64

Introduction

Industrialization is described as the process of transitioning from an agrarian to an industrial sector in which labor is frequently substituted by automated at a large scale. In modern economies, industrial development is considered an engine of economic growth. It helps to increase economic activities and plays a vital role to enhance the level of economic growth (Mahmood et al. 2020). Industrialization not only increases productivity but also raises the standard of living of an economy (Arthur and Sheffrin 2003). On the other hand, industry uses natural resources in production which pollutes

the environment, particularly, in those countries whose growth rate is more than 5% (Munasinghe 1999). Rapid industrialization leads to various environmental issues, especially regarding energy use and carbon emissions.

Environmental pollution is one of the most important concerns for sustainable economic growth. In the current era, the decline in environmental quality has reintroduced the importance of environmental friendliness all over the world (Zafar et al. 2020). In the global contest, every country wants to improve its industry to find out the means of how to compete with the upper hands; as a result, developing countries face severe issues of global warming (Afridi et al. 2019).

In developing countries, CO₂ emissions are increasing because of the excessive use of fossil fuels for getting high growth rates through the industrial process (Saboori and Sulaiman 2013; Hossain 2012). The rise in global temperatures, pollution, and the shifting pattern of rainfall are the signs of rapid pollution and they are all linked to industrialization (Ahmed et al. 2015).

The industrial sector successfully gives the chance for technical innovation in developing countries. In

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the industrial revolution, the usage of environmentally friendly technologies could significantly reduce pollution but unfortunately, the developing countries rely on fossil fuel–related energy resources. Energy has become the lifeline in industrial progress and domestic consumption level. The report of UNIDO (2019) has pointed out that the industrial sector is blameable for greater than 1/3 portion of the world’s non-renewable energy resources and emission intensity. It is estimated that in the following 25 years, the industrial sector will consume energy ranging from 1.8 to 3.5%. In developing countries, the requirement for energy in the industrial sector is almost greater than 50%.

The increasing level of pollution is mostly attributable to the country’s substantial industrialization. Petroleum and oil are used in the industries and transport sector; despite contributing only 0.4% of global CO₂ emissions, Pakistan is gradually increasing its contribution (Shahzad et al. 2017). The report of the World Bank (2007) indicated that Bangladesh emitted roughly one-tenth of global carbon emissions in 2006, even though its 160 million inhabitants accounted for 2.4% of the global population.

Environmental pollution is a debatable issue of the current era (Perera et al. 2019). The rapid deteriorating environmental conditions are one of the biggest problems facing the world today (Ahmed et al. 2015). Wang et al. (2020) recognized the factors which are responsible for excessive CO₂ emissions and pollution. The increasing tendency of GHGs is a hazard to the health of the ecosystem and has insightful effects on human society (Yang et al. 2021b).

South Asia is characterized by a severe increasing population and a variety of environmental issues. Most of the countries in this region are growing faster than the rest of the globe. The economic growth of India is greater than 7% since 2013; it has become the leading economy. Around 60% of the global population lives in South Asia, which heavily relies on the resources related to non-renewable energy and discharges massive amounts of CO₂ emissions (Ikram et al. 2020; Heyhat et al. 2020; Dasvarma 2003). Pakistan enacted environmental restrictions through the National Environmental Policy (2005).¹

Many empirical studies have been conducted to analyze the issues regarding pollution in multiple countries. The lack of a comprehensive study on environmental pollution in South Asia calls for further research to fill up the gap. The objective of this study is to investigate the effects of industrialization and energy consumption on environmental pollution. The purpose of this study is also to find the long-run co-integration and causal relationship between industry and pollution for South Asia for 1984 to 2016.

The study is organized as follows; “Literature review” contains a review of previous studies. The econometric model and methodology are presented in “Econometric model” and “Methodology”, respectively. “Data” is about the data and variables. The empirical results are explained in “Results and discussion” and the study is concluded into “Conclusion”.

Literature review

The main objective of this section is to place the study in a scholarly framework by reviewing the existing research on the relationship between environmental pollution, industrialization, and energy consumption. The review is divided into two sections, the first carries the relationship between industry and pollution, and the second covers the review on the nexus between energy consumption and pollution.

Industrialization and pollution

The long-run relationship between the environment and industrialization in Southeast Asia is checked by Brahmaasrene and Lee (2017), covering the period from 1988 to 2011. Based on the results of the Hausman test, the fixed effects model is employed and the outcomes concluded that industrialization significantly increases CO₂ emissions. Similarly, the study of Kermani et al. (2015) shows the impact of industrialization on CO₂ emissions in the context of Iran for the time of 1980 to 2011. The findings of the VECM and Johansen co-integration test verified that industrialization is one of the significant increasing factors of CO₂ emissions. Xu and Lin (2015) also studied the contribution of industrialization by including the role of exports and coal on CO₂ emissions during the period 1990 to 2011. This study is conducted in the thirty provinces of China which are divided into three (eastern, central, and western) regions. The results showed that industrialization significantly increases CO₂ emissions at the national and provincial levels. The non-linear impacts demonstrated the inverted U-shaped relationship in these three zones.

The study of Farooq et al. (2019) showed the long-run relationship between industrialization, urban population, and energy consumption in the case of India for the annual data covering the period from 1975 to 2018. Similarly, the study by Yang and Usman (2021) found a positive impact of industrialization on pollution for countries with the highest expenditures on health from 1995 to 2018. In the same way, Raheem and Ogebe (2017) shed light on the direct, indirect, and total effects of industrialization on CO₂ emissions in the case of 20 African countries. This study used the PMG technique for the data covering the years from 1980 to 2013. The direct effect showed that industrialization significantly increases environmental degradation, and the total effect revealed that industrialization became the decreasing factor of CO₂ emissions. The long-run

¹ <https://pbit.punjab.gov.pk/system/files/National%20Environmental%20Policy%202005.pdf>

relationship is also confirmed by the Pedroni co-integration test. Nasir et al. (2021) also conducted a study to find out the factors that determine the environmental degradation in Australia for 1980–2014. The findings of the ARDL technique showed that industrialization and energy consumption has a positive influence on CO₂ emissions. The findings of the Granger causality test confirmed the bidirectional causality between industrialization and CO₂ emissions.

The long-run relationship between industrialization and CO₂ emissions is found by Musa et al. (2021) in Nigeria for the time of 1982 to 2018. The outcomes revealed the unidirectional causality from economic growth to CO₂ emissions and industrialization led to economic growth which means that industrialization is indirectly an increasing factor of carbon emissions. Gokmenoglu et al. (2015) also confirmed the long-run relationship between industrialization and CO₂ in Turkey, covering the time 1960 to 2010. Similarly, Liu and Bae (2018) revealed that industrialization significantly increases the CO₂ emissions in the context of China by using the period of 1970 to 2015. The VECM test confirmed the evidence of two-way causality between CO₂ and industrialization. The findings of Kalaycı and Özden (2021) revealed that industrial development is a source of carbon emissions in China from 1960 to 2019.

Energy and pollution

Ghazali and Ali (2019) studied the drivers of CO₂ emissions by extending the STIRPAT model for ten newly industrialized countries from 1991 to 2013. The reason for the selection of these countries is the contribution of 42% of the worldwide CO₂ emissions. The findings revealed that energy consumption is the source of increasing levels of CO₂ emissions. The study of Zhang et al. (2017) reported a positive relationship between energy use and pollution for ten industrialized countries over the period 1971–2013. The findings also showed a unidirectional causality from energy to carbon emissions. The relationship between energy and environment is established for PIIGS countries for 1990–2019 by testing the EKC hypothesis (Balsalobre-Lorente et al. 2022).

The study of Leitao (2021) reported that energy consumption encouraged and GDP discouraged the environmental damage in Portugal for the time of 1970 to 2016. Similarly, the study of Ling et al. (2015) revealed that energy effects impede the environmental quality in Malaysia, and energy is an accelerator factor of carbon emissions in Asia (Sharma et al. 2021). Usman et al. (2021) and Yang et al. (2021a) also exposed that non-renewable energy is a reason for environmental pollution, and non-renewable energy is a source of ecological footprint emissions in the BRICS-T region (Usman and Makhdam 2021).

Usman et al. (2020) examined the environmental quality for 33 upper-middle-income countries for 1994–2017. The long-run estimates demonstrated the direct relationship between energy consumption and ecological footprint (EF). Moreover, one-way causality from energy consumption to EF is confirmed in Asia. Likewise, Afridi et al. (2019) conducted a study for finding the root causes of CO₂ emissions in the SAARC countries. The outcomes exposed that GDP, energy consumption, and population are the estimators of CO₂ emissions. The findings of the study of Sun et al. (2020) revealed that energy consumption significantly increases environmental degradation over 1990–2014 in Sub-Saharan African countries.

Mrabet and Alsamara (2017) conducted a study to find out the driving factors of environmental damage in Qatar by using two indicators of the environment: ecological footprint and CO₂ emissions. The empirical outcomes of ARDL indicated that energy deteriorates the environment. The study of Nosheen et al. (2019) stated that the usage of energy has harmful effects on the environment, using the annual data of Southeast Asian countries. Zandi et al. (2019) also showed that non-renewable energy is considered unfavorable for environmental quality for 105 developed and developing countries, and the findings confirmed the unidirectional causality from energy to the environment. Fatima et al. (2021) also investigated the impact of economic growth, renewable and non-renewable energy, and openness on CO₂ emissions. This study used the annual data of the top ten highly polluting countries. The results confirmed that energy consumption increases CO₂ emissions. Similarly, Hossain (2012) explored a long-run association between CO₂ emissions and energy use for Japan and suggested focusing on energy conservation policies for the sake of low carbon emissions.

Econometric model

Environmental pollution, industrialization, and energy consumption relationship is widely discussed in the literature. Environmental pollution is affected by industrialization and energy consumption (Zafar et al. 2020; Kalaycı and Özden 2021). Industrialization and energy are considered essential to determining environmental pollution (Jun et al. 2020; Farooq et al. 2019). Urbanization is also a critical factor for the environment in South Asia. The relationship between capital and pollution is brought into discussion in the previous literature (Raheem and Ogebe 2017). By incorporating the mentioned variables, the function is stated as

$$POL = f(IN, EC, UR, K) \quad (1)$$

where POL, IN, EC, UR, and K stand for environmental pollution, industrialization, energy consumption, urbanization, and capital. Equation (1) can be formulated in the form of the Cobb–Douglas function:

$$POL = IND^{\alpha_1} EC^{\alpha_2} UR^{\alpha_3} K^{\alpha_4} \quad (2)$$

After taking the logarithm, Eq. 2 is linearized as

$$\ln POL = \alpha_1 \ln IN + \alpha_2 \ln EC + \alpha_3 \ln UR + \alpha_4 \ln K \quad (3)$$

Equation 3 is turned into a panel equation as:

$$\ln POL_{it} = \alpha_0 + \alpha_1 \ln IN_{it} + \alpha_2 \ln EC_{it} + \alpha_3 \ln UR_{it} + \alpha_4 \ln K_{it} + \mu_{it} \quad (4)$$

This study inspects the linkage between environmental pollution, industrialization, energy consumption, urbanization, and capital respectively. In Eq. 4, *POL* is the natural log of environmental pollution and its proxy indicator is CO₂ emissions. *Ln IN* is the natural log of industrialization while *lnEC*, *lnUR*, and *lnK* are the natural logarithms of energy consumption, urbanization, and capital respectively. However, μ is the error term and *i* represents the countries and *t* is used for the period from 1984 to 2016. The term α_0 is the intercept term, and α_1 , α_2 , α_3 , and α_4 are the elasticity of IN, EC, UR, and K respectively.

Methodology

Various methods are used to demonstrate the effect of several economic indicators on environmental pollution in cross-country analysis. The present study employed panel data analysis due to its numerous advantages, such as it is responsible for the perfect interpretation of the parameters and comprises more degree of freedom with more variability in the dataset.

Numerous studies have established that cross-sectional dependence (CSD) is a frequent issue with panel data because the countries are interconnected with each other (Anselin 2001; Pesaran 2004). Furthermore, externalities and unobserved components contribute to the existence of CSD. The study applied all cross-sectional dependence tests, including Breusch-Pagan LM, Pesaran-scaled LM, bias-corrected-scaled LM and Pesaran CD. The null hypothesis for the tests is no cross-sectional dependence (CSD). In the next step, panel unit root tests are applied to find out the order of the integration of all variables for cointegration analysis. The first-generation unit root tests are unreliable because of the presence of CSD, so we have employed the second-generation unit root test recommended by Pesaran (2007). This method has the advantage of controlling CSD while verifying the stationarity of the variables. Accordingly, CIPS and CADF unit root tests have been employed under the null hypothesis of non-stationary while the alternative hypothesis is that all the variables are stable.

The study has employed two distinct long-run estimators, the augmented mean group (AMG) and the common correlated effects mean group (CCEMG) developed by Teal and Eberhardt (2010) and Pesaran (2006), respectively. These methodologies take into account CSD in the panel data set. Furthermore, AMG examines the parameters of non-stationary variables and also considers the heterogeneity among countries.

The first-generation panel cointegration approach is ineffective in addressing the issues of CSD in panel data. As all the concerned variables do not have the property of unit root at their first difference form, the second-generation panel cointegration approach by Westerlund and Edgerton (2008) has been used to inspect whether pollution, industrialization, energy consumption, urbanization, and capital have a long-run relationship in South Asian countries. This approach provides more effective information as compared to the first-generation cointegration approach. The null hypothesis exhibits that no long-run relationship exists among the five concerned variables while on the other hand, the alternative hypothesis takes co-integration. In the end, Dumitrescu and Hurlin (2012) causality test is applied to look into the causation between the variables used in the model.

Data

The data of all variables have been extracted from WDI (2021) for the period of 1984 to 2016 for five South Asian countries (Bangladesh, India, Nepal, Pakistan, and Sri Lanka). The dependent variable is environmental pollution, and industry value added as an indicator of industrialization, energy consumption, urbanization and capital are the independent variables.

Environmental pollution is described as the unwanted variation within the physical, chemical, or organic features of any aspect of the environment that could purpose dangerous consequences on numerous kinds of property, due to this, 9 million people passed away (Carrington 2017). CO₂ emissions (metric tons per capita) are used as a proxy of environmental pollution that is coming from the burning of fossil fuels and the manufacture of cement (use of non-renewable energy sources). Industrialization not only improves the economic growth and standard of living but also increases the pollution level (Musa et al. 2021). It also incorporates the value addition of industrial production, construction, electricity, water, and gas as well. Its calculation does not deduct depreciation of manufactured goods or depletion of natural resources. It is the net production within a sector after the addition of all the production and subtraction of intermediary inputs. It is measured as the value addition of industry (percentage of GDP). Energy consumption is the primary energy used as kg of oil equivalent per capita. As indicated by UNIDO (2019), energy consumption is considered the engine of industrial progress but also increases the emissions intensity.

Table 1 Results of descriptive statistics

Variables	Obs	Mean	Max	Min	Std. dev
POL	165	0.5029	1.6493	0.0402	0.3706
IND	165	23.1802	31.1367	11.8329	4.7881
ENG	165	350.7645	636.5718	106.4292	121.1014
URB	165	23.4331	36.2340	7.1210	7.7607
K	155	23.3538	41.9308	14.1206	6.1312

Table 2 Results of correlation

Variables	POL	IND	ENG	URB	K
POL	1				
IND	0.5863	1			
ENG	0.7756	0.2634	1		
URB	0.6801	0.2965	0.3098	1	
K	0.4199	0.4972	0.3792	-0.0315	1

Gross fixed capital formation (percentage of GDP) is used as capital. Fixed assets consist of land improvements; purchases of equipment and machinery; and construction of roads, rail lines, residential and commercial buildings etc. Urbanization allows for improving the GDP and also increases pollution (Reheem et al., 2017). National statistical offices define urban population (percentage of total) as the people who live in urban regions that are used as the proxy of urbanization.

Descriptive statistics

The outcomes of descriptive statistics are shown in Table 1 for 165 observations of five South Asian countries from 1984 to 2016. The mean value of pollution is 0.5029, its standard deviation is 0.3706 while its maximum and minimum scores are 1.6493 and 0.0402 respectively. Industrialization ranges from 11.8329 to 31.1367, its average value is 23.1802, and the standard deviation is 4.7881. The values of the rest variables are also given in Table 1.

Correlation matrix

Table 2 presents the findings of the correlation among the variables. The correlation coefficient of IN is 0.5863

which indicates a positive relationship with environmental pollution. Energy consumption, urbanization, and capital are directly related to pollution.

Cross-sectional dependence tests

All cross-sectional tests, including Breusch-Pagan LM, Pesaran-scaled LM, bias-corrected-scaled LM, and Pesaran CD are summarized in Table 3. These tests statistically reject the null hypothesis of no cross-sectional dependence (CSD). It demonstrates how any change in one country will have an impact on the other country.

Second-generation unit root tests

The results of CIPS and CADF tests are described in Table 4. According to the panel unit root test, pollution, industrialization, energy consumption, urbanization, and capital have the property of unit root at the level form. However, these panel series reject the null hypothesis and have the order of integration one, after taking their first differences.

Results and discussion

This section encompasses the results of the Augmented Mean Group (AMG) and Common Correlated Effects Mean Group (CCEMG) which are presented in Table 5, while the results of Westerlund co-integration are shown in Table 6. The results of the Dumitrescu-Hurlin (D-H) causality test are mentioned in Table 7.

In Table 5, the results of AMG indicate that industrialization (IN), energy consumption, urbanization, and capital are the significant and polluting factors of the environment because the probability values are less than 1% and 5% level of significance. The positive coefficient of IN indicates that a 1% increase in IN leads to a 0.7806% increase in environmental deterioration and the findings are similar to the previous studies (Appiah et al. 2019; Nasir et al. 2021). Energy

Table 3 Results of cross-sectional dependence tests

Variables	Breusch-Pagan LM	Pesaran-scaled LM	Bias-corrected-scaled LM	Pesaran CD
POL	277.0605***	59.7166***	59.6384***	16.6366***
IND	52.6796***	9.5434***	9.4653***	2.8382*
ENG	247.6089***	53.1310***	53.0476***	15.6716***
URB	317.3794***	68.73213***	68.65400***	3.7157***
K	143.9039***	29.94183***	29.86370***	3.6944***

Probabilities * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4 Results of panel unit root tests

Variables	CIPS		CADF	
	Level	1st difference	Level	1st difference
POL	-1.609	-5.373***	-1.265	-3.124***
IN	-1.332	-5.468***	-0.993	-3.636***
EC	-1.372	-5.062***	-1.109	-3.030***
UR	0.645	-2.867***	-1.265	-2.612**
K	-2.130	-5.345***	2.008	-3.545***

*** and ** denote the 1% and 5% significance levels

is an increasing factor of pollution which is confirmed by the empirical findings. The coefficients of energy consumption and urbanization are 1.5174 and 0.8369 which state that a 1% increase in EC and UR will increase pollution by 1.5174% and 0.8369% respectively and these results are consistent with the study of Rafindadi (2016), Anser (2019), and Abbasi et al. (2020). The increasing trend of the urban population is also creating environmental related issues. There is a need for policies to reduce the migration from rural to urban areas by improving the infrastructure and quality of life in the rural areas. Capital also contributes about 0.056% to pollution.

The outcomes of CCEMG models have been reported in Table 5. Industrialization (IN) and energy consumption (EC) are playing a significant role to increase environmental pollution and their coefficients show that a 1% increase in IN and EC leads to deterioration of the environment by 0.39% and 1.44% respectively. These empirics are consistent with the studies of Liu and Bae (2018), Fatima et al. (2021), and He et al. (2021). The results further expose that a 1% increase in urbanization decreases the environmental quality by 0.41%. The capital also has a positive coefficient indicating that a 1% increase in capital is linked with a 0.115% increase in environmental pollution which is also found by Kamal et al. (2021).

Table 5 Empirical results

Dependent variable: Environmental Pollution				
Variables	AMG		CCEMG	
	Coeff	Prob	Coeff	Prob
LIN	0.7806**	0.034	0.3915**	0.035
LEC	1.5174***	0.000	1.4401***	0.000
LUR	0.8369***	0.000	0.4137**	0.013
LK	0.0563***	0.001	0.1148**	0.028
C	-10.8740***	0.000	-14.3494***	0.000
Obs	155		155	

*** and ** denote the 1% and 5% significance levels

Table 6 Results of Westerlund co-integration test

Statistics	Values	Z-values	P-values
Gt	-3.603	-2.711	0.003
Ga	-13.068	-0.033	0.049
Pt	-6.546	-1.608	0.040
Pa	-18.753	-2.786	0.003

The results of the Westerlund co-integration test are described in Table 6. The findings reported that environmental

Table 7 Results of Dumitrescu-Hurlin causality test

H ₀ : no causality	W-Stat	Z-Stat	Prob	Conclusion
LIN does not cause LPOL	6.4561	3.9999	0.0000***	LIN ↔ LPOL
LPOL does not cause LIN	4.8226	2.47063	0.0135**	
LEC does not cause LPOL	4.7116	2.3668	0.0179**	LEC → LPOL
LPOL does not cause LEC	2.8322	0.6085	0.5428	
LUR does not cause LPOL	3.3341	1.0781	0.2810	-
LPOL does not cause LUR	3.1882	0.9415	0.3464	
LK does not cause LPOL	4.1583	1.8491	0.0644*	LK → LPOL
LPOL does not cause LK	3.4590	1.1949	0.2321	
LEC does not cause LIN	4.7921	2.4421	0.0146*	LEC → LIN
LIN does not cause LEC	3.5814	1.3095	0.1904	
LUR does not cause LIN	9.5045	6.8599	0.0000***	LUR → LIN
LIN does not cause LUR	5.6427	3.2379	0.0012***	
LK does not cause LIN	3.6557	1.3790	0.1679	-
LIN does not cause LK	1.9502	-0.2166	0.8285	
LUR does not cause LEC	3.3576	1.0002	0.2713	-
LEC does not cause LUR	3.0956	0.8549	0.3926	
LK does not cause LEC	2.8185	0.5956	0.5514	-
LEC does not cause LK	2.7460	0.5279	0.5976	
LK does not cause LUR	6.1340	3.6975	0.0002***	LK ↔ LUR
LUR does not cause LK	5.8716	3.4521	0.0006***	

*** and ** denote the 1% and 5% significance levels

pollution, industrialization, energy use, urbanization, and capital are co-integrated in the long run in South Asia because the probability values of Westerlund and Edgerton (2008) are less than 5% that reject the null hypothesis and accept the alternative hypothesis of co-integration.

Table 7 shows the results of the Dumitrescu-Hurlin causality test which is applied to find the causality between the variables. There exist unidirectional causalities from energy consumption to pollution, capital to pollution, and urbanization to industrialization. The results show that energy consumption increases the trends of industrialization. The findings also confirm the bidirectional causality between capital and urbanization. A bidirectional causality is observed between industrialization to environmental pollution, capital, and urbanization. The results are consistent with the findings of Nasir et al. (2021) and Liu and Bae (2018).

Conclusion

Industrialization has become an essential part of economic growth for both developing and developed countries. Economic growth and increasing the prosperity of economic agents are only possible because of the industrial process. Fast industrialization and excessive use of energy lead to creating considerable environmental problems. This study has been conducted to find out the environmental consequences of industrialization and energy consumption by incorporating the role of urbanization and capital by using the data of 1984 to 2016. Afghanistan, Bhutan, and Maldives are excluded because of the non-availability of the data, so the panel of five countries, among them Pakistan, India, Bangladesh, Nepal, and Sri Lanka, are nominated. The study employs Augmented Mean Group (AMG) and Common Correlated Effects Mean Group (CCEMG) estimators to analyze the panel data from 1984 to 2016 for South Asia. As CIPS and CADF panel unit root tests confirmed that all the series have become stable at their first difference, and the long-run relationship is confirmed by the Westerlund co-integration test. The empirics of AMG and CCEMG reported that industrialization, energy, urbanization, and capital lead to enhance the environmental pollution in South Asia.

The findings suggest that South Asian countries should focus to reduce the excessive use of non-renewable energy for a better environment by emphasizing renewable energy sources in the industrial sector. The results of this study stressed taking some measures to improve the environmental quality without affecting the production level of the industrial sector. The governments should identify the goods which are harmful to produce in their countries and should focus on the imports of these goods from other countries to reduce pollution. South Asian countries should also increase the export of goods and services which do not affect the environment. The policies

regarding exports and imports will not affect the production level and trade balance as well. The study also purposed that employment opportunities and infrastructure facilities should be given in the rural areas to control the negative influence of urbanization. The government should also design such policies which increase capital and investment opportunities for green technology to reduce pollution in South Asia.

This study focused on the role of non-renewable energy use and industrialization, and there is a need to emphasize the role of renewable energy in the environmental pollution in South Asia.

Author contribution All authors contributed to the study's conception and design. Material preparation, data collection, and analysis were performed by Sumaira and Hafiz Muhammad Abubakar Siddique. The first draft of the manuscript was written by both authors. Both authors read and approved the final manuscript.

Data availability Our manuscript contains data, which will be made available at reasonable request.

Declarations

Ethical approval The manuscript has not been submitted to any other journal. The submitted work is original and has not been published elsewhere in any form or language (partially or in full). A single study has not to be split up into several parts to increase the number of submissions. Results have been presented, honestly, and without fabrication, falsification, or inappropriate data manipulation (including image-based manipulation). No data, text, or theories by others are presented as if they were the author's own ("plagiarism").

Consent to participate All the authors made substantial contributions to all the segments of the articles, drafted the work, approved the final version, and agreed to be accountable and responsible for the article.

Consent for publication The authors are responsible and accountable for all the segments of the manuscript. It is our original research work and we want to publish it.

Competing interests The authors declare no competing interests.

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