Social management-CO2 emissions nexus in Pakistan: Do economic asymmetries matter?

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Abstract

The study makes an effort to examine the association between education, health expenditure, GDP per capita, and pollution emissions for Pakistan from 1991 to 2019. The study uses a non-linear ARDL model to capture short-run and long-run asymmetric effects among variables. The findings confirm the existence of an asymmetric relationship among variables in the short-run and long-run. Positive shocks of education, health expenditures, and GDP per capita reveal that education and health expenditures have a negative influence on carbon emissions, however, GDP has a positive influence on carbon emissions in the long-run. On the other hand, negative shocks of education, health expenditures, and GDP per capita reveal that education has no significant impact on carbon emissions, while a decrease in health expenditures and GDP per capita leads to a reduction in carbon emissions in the long run. These results have imperative implications for analysts as well as management of the Pakistan economy.

Introduction

The industrial revolution has, on one side, improved the living standards of the common man, whereas, on the other side, it has seriously jeopardized the environmental condition of the globe. The socio-economic condition of people improved but the large-scale emissions of greenhouse gases are also wreaking havoc on humanity in the form of environmental hazards. The major reason behind emissions of such gases is increased socioeconomic activity due to rising population and ever-increasing demand and as a result, mankind has increased the consumption of fossil fuels that are the main contributor in emanations of greenhouse gasses particularly CO_2 emissions (Shan et al., 2016; Wang et al., 2017). Though socio-economic development is very necessary because it keeps the pace of the economy going due to which the population of a country stays away from menaces of poverty, unemployment, diseases, illiteracy etc. and the overall standard of living of a common man improves. However, the management of socio-economic development by governments and policymakers must be done in a way that the goals of socio-economic development and environmental protection go side by side (Fang et al., 2017; Wang et al., 2017). The management of sustainable socio-economic development has been given prime importance by world leaders. They all agreed that management policies related to social and economic development should be designed in a way that they could emancipate mankind from the clutches of poverty, illiteracy, and disease by ensuring the low level of CO_2 emissions and leaving a green and less polluted environment for future generations (Guterres, 2017).

The literature on the effects of economic development on environmental quality is ever increasing. Most of these studies have tested this nexus by using the Environmental Kuznets Curve (EKC) model an inverted U-shaped link between economic growth and CO_2 emission. However, the findings of these studies are mixed. A large number of studies have confirmed the presence of the EKC hypothesis which suggests that economic growth has successfully managed the goal of environmental protection and reduced the discharges of CO_2 and other greenhouse gases in the environment (Apergis, 2016; Pablo-Romero et al., 2017; Solarin et al., 2017; Aslam et al., 2021). Some of the studies have not supported the EKC hypothesis or in other words, economic growth has not minimized the CO_2 emissions or both the goals of economic growth and environmental protections are moving in the opposite direction (Mert and Bölük, 2016; Dogan and Turkekul, 2016). Then, there is another strand of literature that have included other variables in their growth-environment nexus like Atici (2009), Shahbaz (2013), Usman et al. (2020) included energy consumption; Jafari et al. (2021) and Ullah et al. (2020) included urbanization; Baek & Kim (2011) and Chisti et al. (2020) included trade openness and globalization; Acheampong (2019) and Tamazian et al. (2009) included financial development; Apergis & Ozturk (2015) and Dutt (2009) included governance quality; Zhang & Lin (2012) included population size; Ravallion et al. (2000), Zhang & Zhao (2014) included income inequality.

Recently, environmental researchers have shown their interest in examining the growth-environment nexus in the light of the management of social aspects of the economy. Simply, we can say that empirics have now started to include various indicators of human capital and two of the most common indicators are education and health (Chaabouni and Saidi, 2017; Yao et al.2019). Education can impact the environment quality in either way i.e. positive or negative. Education can improve environmental quality by creating more awareness about the detrimental impact of a dirty environment. Moreover, the education will also make the people more aware about consuming clean and green energy that will ultimately reduce CO_2 emissions (Jacksohn et al. 2018). Furthermore, the well-educated and highly trained managers and staff in the firms have their inclination towards more

efficient use of energy (Cagno and Trianni, 2013; Lan and Munro, 2013). Conversely, education can also hurt the environmental quality by creating a growth effect in the economy as a high level of education in the country can promote growth activities that could lead to a more contaminated environment. Similarly, increased investment in the education sector will also push the energy demand upward which will also harm the environmental quality (Katircioglu et al., 2020). While there is consensus among most of the researchers that the improved health condition in the country could induce the people to work more which will help the economy to grow and result in more CO_2 emissions. Moreover, improved health condition is attached to more health spending which spikes the energy demand and eventually enhances the CO_2 emissions (Farooq et al., 2019 and Apergis et al., 2020).

Against this backdrop, the importance of management concerning social and economic development increases particularly, for a struggling economy like Pakistan. The selection of Pakistan is an interesting choice because its total health and education spending are about 4.8% of its GDP in the year 2017 (World Bank, 2017). Moreover, the economy of Pakistan has also squeezed in the year 2020 (World Bank, 2020). Without proper management of the resources, the economy as fragile as Pakistan could dig deep further into the well and would not be able to achieve the target of sustainable social and economic development. Hence, in this study, we want to examine the impact of Pakistan's management of social and economic development on the environmental quality of the country. Besides, this study has used the time series data which is better in the sense that it does not suffer from aggregation bias. Furthermore, the study has used the novel asymmetric ARDL technique for the estimation which provides us with an opportunity to differentiate between the positive and negative impacts of the right-hand side variables on the left-hand side of the variable.

The next section describes model and method applications. In the third section, we have cast light on the data and methodology used to estimate the relationship. The fourth section is about results and the conclusion is provided in section five.

Model And Methods

In this empirical study, we need to analyze social and economic development-CO_2 emissions nexus and constructed the following model:

$$\mathrm{CO}_{2,t} = \omega_0 + \phi_1 \mathrm{Education}_t + \phi_2 \mathrm{Health}_t + \phi_3 \mathrm{GDP}_t + \phi_4 \mathrm{FD}_t + \epsilon_t (1)$$

Pakistan CO_2 emissions depend on education, health expenditure, economic development (GDP), and the level of financial development (FD) in Pakistan. However, Eq. (1) is a long-run model and only provides us with the long-run estimates, but we are also interested in the short-run estimates. Hence, we have redefined Eq. (1) into the error correction format is presented below:

$$\Delta \mathrm{CO}_{2,t} = \omega_0 + \sum_{k=1}^{n} \beta_{1k} \Delta \mathrm{CO}_{2,t-k} + \sum_{k=0}^{n} \beta_{2k} \Delta \mathrm{Education}_{t-k} + \sum_{k=0}^{n} \beta_{3k} \Delta \mathrm{Health}_{t-k} + \sum_{k=1}^{n} \beta_{4k} \Delta \mathrm{GDP}_{t-k} + \sum_{k=0}^{n} \beta_{5k} \Delta \mathrm{FD}_{t-k} + \omega_1 \mathrm{CO}_{2,t-1} + \omega_2 \mathrm{Education}_{t-1} + \omega_3 \mathrm{Health}_{t-1} + \omega_4 \mathrm{GDP}_{t-1} + \omega_5 \mathrm{FD}_{t-1} + \varepsilon_t \qquad (2)$$

Specification (2) can now be called as ARDL model of Pesaran et al. (2001), which provides us with both short and long-run estimates simultaneously. The short-run results can be derived from the coefficients that are connected to first-difference variables, and the long-run results can be interpreted from the coefficients $\mu_2 - \mu_6$ normalized on μ_1. However, in time series analysis, the long-run results are considered spurious unless we find cointegration between them. To that end, Pesaran et al. (2001) proposed a bounds F-test, which confirms the joint significance of lagged level variables if the calculated value is greater than the tabulated value. Moreover, an alternative test is known as the error correction (ECM_{t-1}) test, which approves the cointegration if the estimate of ECM_{t-1} is negatively significant. Another advantage of this model is that we don't need to check the stationary of the variables because it can deal with I(0) and I(1) variables at the same time. Further, this model can produce efficient results in the case of a small sample size (Panopoulou & Pittis, 2004). Last but not least, this model allows us to include the dynamic process in the short-run, which highlights feedback effect if any, and control endogeneity and multicollinearity

(Bahamani-Oskooee et al. 2020). To assess the asymmetries among social and economic management-environmental sustainability, we employ partial sum procedures introduced by Shin et al. (2014):

$$\text{Education}^{+}{}_{t} = \sum_{n=1}^{t} \Delta\text{Education}^{+}{}_{t} = \sum_{n=1}^{t} \max(\text{Education}^{+}{}_{t}, 0) \quad (3a)$$

$$\text{Education}^{-}{}_{t} = \sum_{n=1}^{t} \Delta\text{Education}^{-}{}_{t} = \sum_{n=1}^{t} \min(\Delta\text{Education}^{-}{}_{t}, 0) \quad (3b)$$

$$\text{Health}^{+}{}_{t} = \sum_{n=1}^{t} \Delta\text{Health}^{+}{}_{t} = \sum_{n=1}^{t} \max(\Delta\text{Health}^{+}{}_{t}, 0) \quad (4a)$$

$$\text{Health}^{-}{}_{t} = \sum_{n=1}^{t} \Delta\text{Health}^{-}{}_{t} = \sum_{n=1}^{t} \min(\Delta\text{Health}^{-}{}_{t}, 0) \quad (4b)$$

$$\text{GDP}^{+}{}_{t} = \sum_{n=1}^{t} \Delta\text{GDP}^{+}{}_{t} = \sum_{n=1}^{t} \max(\Delta\text{GDP}^{+}{}_{t}, 0) \quad (5a)$$

$$\text{GDP}^{-}{}_{t} = \sum_{n=1}^{t} \Delta\text{GDP}^{-}{}_{t} = \sum_{n=1}^{t} \min(\Delta\text{GDP}^{-}{}_{t}, 0) \quad (5b)$$

In the above equations Education^{+}, Health^{+}, GDP^{+} represent the positive change, whereas, the Education^{-}, Health^{-}, GDP^{-} represent the negative changes. Next, we will replace partial sum variables into the original equation:

$$\Delta CO_{2,t} = \omega_0 + \sum_{k=1}^{n} \delta_{1k} \Delta CO_{2,t-k} + \sum_{k=0}^{n} \delta_{2k}\, \Delta\text{Education}^{+}{}_{t-k} + \sum_{k=0}^{n} \delta_{3k}\, \Delta\text{Education}^{-}{}_{t-k} + \sum_{k=0}^{n} \delta_{4k}\, \Delta\text{Health}^{+}{}_{t-k} + \sum_{k=0}^{n} \delta_{5k}\, \Delta\text{Health}^{-}{}_{t-k} + \sum_{k=0}^{n} \delta_{6k}\, \Delta\text{GDP}^{+}{}_{t-k} + \sum_{k=0}^{n} \delta_{7k}\, \Delta\text{GDP}^{-}{}_{t-k} + \sum_{k=0}^{n} \beta_{8k}\, FD_{t-k} + \omega_1 CO_{2,t-1} + \omega_2 \text{Education}^{+}{}_{t-1} + \omega_3 \text{Education}^{-}{}_{t-1} + \omega_4 \text{Health}^{+}{}_{t-1} + \omega_5 \text{Health}^{-}{}_{t-1} + \omega_6 \text{GDP}^{+}{}_{t-1} + \omega_7 \text{GDP}^{-}{}_{t-1} + \omega_8 FD_{t-1} + + \varepsilon_t \quad (6)$$

After entering the partial sum variables in place of original variables, the new Eq. (6) is known as the NARDL of Shin et al. (2014), which is a new form of the ARDL model. This method is subject to the same cointegration test and critical values as Pesaran et al. (2001) proposed for the linear ARDL model. Next, long-run and short-run asymmetries are confirmed via Wald-test. We run the Hatemi-J (2012) nonlinear causality test to examine the causal link between social and economic development and CO2 emissions for Pakistan during the period 1991–2019.

Data

We attempt to investigate the dynamic impact of social and economic factors on CO2 emissions for the set of annual data from 1991 to 2019 in the case of Pakistan. The CO2 emissions is measured in kilotons, which are taken as the dependent variable in our analysis. The years of schooling and general government health expenditure are used as a proxy for social development, while GDP per capita is used for economic development and financial development is used as a control variable. CO2 emissions and GDP per capita variables are transferred into natural logarithms. The detail of definitions and data sources are also reported in Table 1. Descriptive statistics show that mean of CO2, education, health, GDP, and FD are 11.78kt, 4.02years, 0.91%, 6.83 US$, 21.8%, while the standard deviations are 0.35kt, 0.97years, 0.31%, 0.14 US$, 3.98%, respectively.

Table 1
Definitions and data description

Variable	symbol	Definitions	Mean	Std. Dev.	Min	Max
CO2 emissions	CO2	CO2 emissions (kt)	11.78	0.35	11.13	12.2
Years of schooling	Education	Average years of schooling	4.02	0.97	2.40	5.20
Health expenditure	Health	Domestic general government health expenditure (% of GDP)	0.91	0.31	0.49	1.52
GDP per capita	GDP	GDP per capita (constant 2010 US$)	6.83	0.14	6.62	7.09
Financial development	FD	Domestic credit to private sector (% of GDP)	21.8	3.98	15.39	28.7

Empirical results and discussion

Before exploring the long-run cointegration among variables, the integration properties of variables have been confirmed. For that purpose, we have applied with break unit root test and without break unit root test. Table 2 demonstrates the outcomes of both unit root tests. The findings of both tests demonstrate that education is stationary at level; however, all other variables are stationary at the first difference. The study has used ARDL and NARDL models to check the linear and nonlinear relationships among the variables in the short-run and long-run.

Table 2
Unit root testing

	Unit root test without break			Unit root test with break				
	Level	First difference	Decision	Level	Break date	First difference	Break date	Decision
CO2	-1.986	-6.077***	I(1)	-2.865	2003	-7.899***	2007	I(1)
Education	-2.651*		I(0)	-4.254*	2000			I(0)
Health	-2.018	-6.289***	I(1)	-2.865	2002	-7.398***	2006	I(1)
GDP	-0.356	-3.543**	I(1)	-1.896	2002	-4.356*	2004	I(1)
FD	-1.168	-4.068***	I(1)	-3.986	2008	4.567**	2004	I(1)

In Table 3, long-run results of ARDL show that education has a positive significant impact on pollution emissions. The coefficient estimate implies that 1 percent increase in education in the long-run results in a 0.123 percent increase in pollution emissions. Health expenditure has a negative significant effect on carbon emissions in the long-run. The findings reveal that a 1 percent upsurge in health expenditures results in a 0.140 percent decrease in pollution emissions. GDP per capita is significantly and positively associated with pollution emissions in the long-run. As a result of 1 percent increase in GDP per capita, pollution emissions decrease by 1.202 percent. Financial development has an insignificant effect on pollution emissions as demonstrated by an insignificant coefficient estimate of financial development. The short-run results of ARDL demonstrate that only education variable positively and significantly affects pollution emissions. However, health expenditures, GDP per capita, and financial development have no effect on pollution emissions in the short-run. Diagnostic tests reveal that long-run association among variables exists as established by significant findings of F-Statistics and ECM. The value of ECM is negative as required, i.e., 0.757, which demonstrates that 75 percent convergence towards stability will be achieved in one year. The LM test is performed to check the serial correlation and Breusch-Pagan-Godfrey (BPG) test is performed to check the heteroscedasticity. The findings of both tests reveal that there is no issue of heteroscedasticity and correlation in the models. RESET test result confirms the correct specification of the model.

The long-run findings of NARDL reveal that the positive shocks of education exert a significant negative effect on pollution emissions. In other words, a 1 percent increase in education decreases pollution emissions by 0.248 percent in Pakistan. On the other hand, negative shocks of education exert no impact on pollution emissions in the long run. The study also reveals that

positive and negative shocks of health expenditures have a significant negative effect on pollution emissions in Pakistan. In a more precise manner, a 1 percent upsurge in positive and negative components of health expenditures, in the long-run, decreases pollution emissions by 0.627 percent and 0.501 percent respectively. In addition, the positive shocks of GDP have a positive effect on carbon emissions. The coefficient estimates show that a 1 percent increase in GDP per capita results in increasing pollution emissions by 2.843 percent. In contrast, the negative shocks of GDP per capita result in decreasing pollution emissions. The findings reveal that a 1 percent increase in GDP per capita results in reducing 2.376 percent carbon emissions in the long-run.

The finding is compatible with Mahalik et al. (2021), who noted that education level is improving environmental quality in BRICS. Education contributes to the formation of human capital by making them more efficient and capable which leads to growth and economic development. It empowers the society to develop the processes and methods of green production, economic development, and achieve innovation. Consequently, education contributes as a source to encourage the education of energy for firms and consumers for the adoption and generation of various sources of renewable energies. Education helps in increasing consumption of renewable energy because of knowledge and awareness about the security of energy (Desha et al., 2015). In the budget of 2018, the government of Pakistan's allocation for the education sector is only 2 percent of GDP which is the quite worst scenario.

This finding is reliable with Apergis et al. (2020), who noted that health expenditure has a favorable impact on the environment. The transition in the structure of health expenditures has been coupled across countries due to rising trade activities and environmental pollution. The health sector consumes energy to a large amount. Specialist medical equipment, such as magnetic resonance imaging machines, computed tomography scans, and magnetic resonance tomography, all consume energy in high volumes. The classification of indirect and direct use of energy in the health sector is critical for redesigning policies for more effective use of energy and reduction of carbon emissions. Reduction in health expenditures through dietary changes results in reducing carbon emissions. The healthy food system is directly linked with healthcare expenditure that positively contributes to reducing carbon emissions. Thus, health care expenditure raises life expectancy by reducing the environmental pollution. Our findings agree with Aslam et al. (2021), GDP has an asymmetric influence on CO_2 emission in China. The possible reason is that the fast economic activities of Pakistan's economy cannot resolve the environmental pollution problem. Since Pakistan is executing many dirty growth initiatives in the economy.

Financial development has a negative influence on pollution emissions in the long-run. The coefficient estimates reveal that in response to 1 percent upsurge in financial development, in long-run, pollution emissions reduce by 2.376 percent. The short-run findings of NARDL reveal that positive and negative shocks of education have no significant impact on pollution emissions in Pakistan. In addition, positive shocks of health expenditure do not have an impact on pollution emissions; however, negative shock of health expenditure has a negative influence on pollution emissions in the short-run. The positive shocks of GDP have a positive significant impact on pollution emissions and negative shock of GDP has a significant negative impact on pollution emissions in the short-run. Financial development also negatively affects pollution emissions in Pakistan in the short-run.

The outcomes of diagnostic tests demonstrate the coefficient estimates of F-Statistics and ECM are statistically significant, confirming the existence of long-run relationship among variables. The value of ECM is -0.832, which demonstrates that 83 percent convergence towards stability will be achieved in one year. The findings of LM test and BPG test confirm the absence of heteroscedasticity and correlation in the models. RESET test findings reveal that model is correctly specified. Furthermore, the stability of the model is also confirmed from the findings of CUSUM and CUSUMSQ tests. The Wald test outcomes specify that long run asymmetric effect of education, health, and GDP on CO_2 emissions is dominant in short run. Figures 1–3 depict the cumulative effect of education, health, and GDP on CO_2 emission infers that asymmetries exist between concern variables in positive and negative shocks.

Table 3
ARDL and NARDL estimates

Variable	Coefficient	S.E	t-Stat	Prob.	Variable	Coefficient	S.E	t-Stat	Prob.
Short-run					**Short-run**				
D(EDUCATION)	0.093**	0.041	2.250	0.039	D(EDUCATION_POS)	-0.117	0.158	0.738	0.514
D(HEALTH)	-0.014	0.041	0.339	0.739	D(EDUCATION_POS(-1))	0.277	0.187	1.485	0.234
D(GDP)	0.309	0.376	0.822	0.423	D(EDUCATION_NEG)	-0.005	0.583	0.009	0.993
D(FD)	0.000	0.002	0.002	0.999	D(EDUCATION_NEG(-1))	0.627	0.805	0.778	0.493
Long-run					D(HEALTH_POS)	-0.033	0.230	0.144	0.895
EDUCATION	0.123**	0.048	2.558	0.021	D(HEALTH_POS(-1))	0.566	0.382	1.483	0.235
HEALTH	-0.140**	0.060	2.335	0.033	D(HEALTH_NEG)	-0.345*	0.205	1.681	0.191
GDP	1.202***	0.208	5.771	0.000	D(HEALTH_NEG(-1))	0.227	0.201	1.129	0.341
FD	0.001	0.003	0.002	0.999	D(GDP_POS)	3.030**	1.377	2.201	0.031
C	3.277***	1.172	2.796	0.013	D(GDP_POS(-1))	-1.978	2.075	0.953	0.411
Diagnostic					D(GDP_NEG)	-3.840**	1.797	2.137	0.032
F-test	8.404***				D(GDP_NEG(-1))	1.749	1.449	1.207	0.314
ECM(-1)	-0.757	0.152	4.967	0.000	D(FD)	-0.005*	0.003	1.666	0.100
LM	1.580				D(FD(-1))	0.014	0.009	1.614	0.205
BPG	0.542				**Long-run**				
RESET	0.877				EDUCATION_POS	-0.248*	0.147	1.687	0.097
CUSUM	S				EDUCATION_NEG	-0.243	0.597	0.408	0.711
CUSUMsq	S				HEALTH_POS	-0.627***	0.166	3.783	0.032
					HEALTH_NEG	-0.501**	0.251	1.993	0.140
					GDP_POS	2.834***	0.771	3.674	0.035
					GDP_NEG	-2.376**	1.093	2.174	0.118
					FD	-0.013**	0.006	2.110	0.125
					C	11.43***	0.122	93.52	0.000
					Diagnostic				
					F-test	6.287***			
					ECM(-1)	-0.832***	0.306	2.718	0.014
					LM	1.056			
					BPG	1.094			
					RESET	0.297			
					CUSUM	S			
					CUSUMsq	S			

Note: ***p < 0.01; **p < 0.05; *p < 0.1

Variable	Coefficient	S.E	t-Stat	Prob.	Variable	Coefficient	S.E	t-Stat	Prob.
					Education-LR	5.401***			
					Education-SR	0.123			
					Health-LR	6.756***			
					Health-SR	0.136			
					GDP-LR	13.45***			
					GDP-SR	6.565***			
Note: ***p < 0.01; **p < 0.05; *p < 0.1									

Table 4 reports the symmetric and asymmetric causality estimates among the concern variables by employing Hatemi-j (2012) test. Symmetric causality runs from education to CO2 and GDP to CO2 in Pakistan. While there is no symmetric causality exist between health and CO2. Table 4 also shows causal link runs from education to CO2 with regard to asymmetric causality. While the negative shock of health expenditure and positive shock of GDP is significant causal nexus with CO2 emissions. The asymmetric causal link between a positive shock in health and CO2 is significant. While a similar finding is observed for negative shock in GDP and CO2.

Table 4
Non-asymmetric and asymmetric causality test

Null Hypothesis:	F-Stat	Prob.	Null Hypothesis:	F-Stat	Prob.
EDUCATION →CO2	11.86	0.000	EDUCATION_POS →CO2	12.02	0.000
CO2 →EDUCATION	0.787	0.467	CO2 →EDUCATION_POS	0.928	0.411
HEALTH →CO2	1.710	0.204	EDUCATION_NEG →CO2	3.306	0.057
CO2 →HEALTH	0.595	0.560	CO2 →EDUCATION_NEG	2.817	0.082
GDP →CO2	3.867	0.036	HEALTH_POS →CO2	0.223	0.802
CO2 →GDP	3.855	0.037	CO2 →HEALTH_POS	0.623	0.546
FD →CO2	0.879	0.429	HEALTH_NEG →CO2	2.699	0.091
CO2 →FD	1.504	0.244	CO2 →HEALTH_NEG	1.018	0.379
HEALTH →EDUCATION	1.285	0.297	GDP_POS →CO2	4.473	0.024
EDUCATION →HEALTH	2.468	0.108	CO2 → GDP_POS	2.042	0.155
GDP →EDUCATION	1.054	0.366	GDP_NEG →CO2	0.660	0.527
EDUCATION →GDP	7.475	0.003	CO2 →GDP_NEG	2.357	0.119
FD →EDUCATION	0.710	0.503	EDUCATION_NEG →EDUCATION_POS	0.184	0.833
EDUCATION →FD	0.708	0.504	EDUCATION_POS →EDUCATION_NEG	4.058	0.032
GDP →HEALTH	0.962	0.398	HEALTH_POS →EDUCATION_POS	0.229	0.797
HEALTH →GDP	2.477	0.107	EDUCATION_POS →HEALTH_POS	1.466	0.254
FD →HEALTH	0.767	0.476	HEALTH_NEG → EDUCATION_POS	2.112	0.146
HEALTH →FD	0.684	0.515	EDUCATION_POS →HEALTH_NEG	2.144	0.142
FD →GDP	1.671	0.211	GDP_POS →EDUCATION_POS	0.998	0.385
GDP →FD	3.606	0.044	EDUCATION_POS →GDP_POS	4.787	0.019
			GDP_NEG →EDUCATION_POS	1.910	0.173
			EDUCATION_POS →GDP_NEG	1.186	0.325
			FD →EDUCATION_POS	0.673	0.521
			EDUCATION_POS →FD	0.776	0.473
			HEALTH_POS →EDUCATION_NEG	0.949	0.403
			EDUCATION_NEG →HEALTH_POS	4.915	0.018
			HEALTH_NEG →EDUCATION_NEG	5.064	0.016
			EDUCATION_NEG →HEALTH_NEG	0.686	0.515
			GDP_POS →EDUCATION_NEG	2.584	0.099
			EDUCATION_NEG → GDP_POS	0.247	0.783

Note: ***p < 0.01; **p < 0.05; *p < 0.1

Null Hypothesis:	F-Stat	Prob.	Null Hypothesis:	F-Stat	Prob.
			GDP_NEG →EDUCATION_NEG	0.525	0.599
			EDUCATION_NEG →GDP_NEG	1.264	0.303
			FD →EDUCATION_NEG	0.278	0.760
			EDUCATION_NEG →FD	3.140	0.064
			HEALTH_NEG →HEALTH_POS	0.240	0.789
			HEALTH_POS →HEALTH_NEG	13.01	0.000
			GDP_POS →HEALTH_POS	2.173	0.139
			HEALTH_POS →GDP_POS	1.026	0.376
			GDP_NEG →HEALTH_POS	0.362	0.701
			HEALTH_POS →GDP_NEG	2.833	0.081
			FD →HEALTH_POS	0.639	0.538
			HEALTH_POS →FD	2.967	0.073
			GDP_POS →HEALTH_NEG	0.536	0.593
			HEALTH_NEG →GDP_POS	1.421	0.264
			GDP_NEG →HEALTH_NEG	0.404	0.673
			HEALTH_NEG →GDP_NEG	0.859	0.438
			FD →HEALTH_NEG	0.709	0.504
			HEALTH_NEG →FD	1.712	0.205
			GDP_NEG →GDP_POS	1.585	0.228
			GDP_POS →GDP_NEG	2.148	0.142
			FD →GDP_POS	2.907	0.077
			GDP_POS →FD	4.774	0.020
			FD →GDP_NEG	0.023	0.978
			GDP_NEG →FD	1.698	0.207

Note: ***p < 0.01; **p < 0.05; *p < 0.1

Conclusion And Implications

This study examines the association among education, health expenditures, GDP per capita, and carbon emission in Pakistan using time-series annual data for the period 1991 to 2019 by employing the NARDL approach. Before estimating NARDL regression, the unit root test with structural break and without structural break unit root tests are conducted to confirm the stationarity properties of all the variables. After estimating the NARDL model, various diagnostic tests are performed to test the reliability of the model. The Wald test results confirm the existence of long-run and short-run asymmetric relationships among dependent and independent variables. We conclude that positive shock in education is negatively associated with pollution emissions in the long-run. In contrast, negative shocks in education do not have a significant impact on pollution emissions. This finding suggests that in the long-run, an increase in education results in improving environmental quality. In the case of health expenditures, the study concludes that positive and negative shocks in health expenditures result in reducing pollution emission that leads to improvement in the quality of the environment in the long run. However, a positive shock in GDP per capita

enhances pollution emissions and a negative shock in GDP per capita enhances environmental quality. In the short-run, the negative shocks in health expenditures and GDP per capita are negatively linked with pollution emissions. These findings reveal the important role of negative shocks in health expenditures and GDP per capita in improving environmental quality in the short-run. However, education's role in determining environmental quality is insignificant in the short run.

Regarding policy, the government of Pakistan should raise the share of government education and health expenditure to environmental sustainability. Education and health expenditure significantly reduce CO2 emissions, thus policymakers and authorities should focus on long-term education and health care policies in Pakistan. Management long-term policy goals can enrich environmental sustainability via education and health expenditure in the economy. A comprehensive policy is demanded in the context of government expenditure, green economic growth, and environmental quality in Pakistan. All the reliable stakeholders like consumers, producers, sponsors, and government must play their role in decreasing CO2 emissions. The number of educational levels in recent years is increased, but the quality level of education is not increasing in Pakistan. The quality level of education is very crucial in environmental sustainability. Federal and provincial administration should play a positive role in awareness of environmental sustainability, thus seminars, workshops, conferences are organized by management at the grassroots level in the country. Government should raise the economic growth at the lower cost of environmental pollution in Pakistan. Management should adopt green economic growth by using the social factors in the economy.

The study has valuable limitations. The study is only conducted for Pakistan; a similar analysis should be conducted for other economies. Future studies may scrutinize the higher educational level, technological shocks in health, and CO2 emissions relationship using advanced time series econometric approaches.

Declarations

Author contribution

Muhammad Rizwanullah: conceptualization, formula analysis, investigation, writing the original draft, data collection, methodology, and formal analy-sis. Muhammad Nasrallah and Muhammad Tayyab Sohail: writing review, investigation, software, and method-ology. Lizhi Liang: supervision, investigation, data correction, formula analysis, methodology, and editing

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This is an observational study. We confirmed that no ethical approval is required. Consent to participate is not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Figures

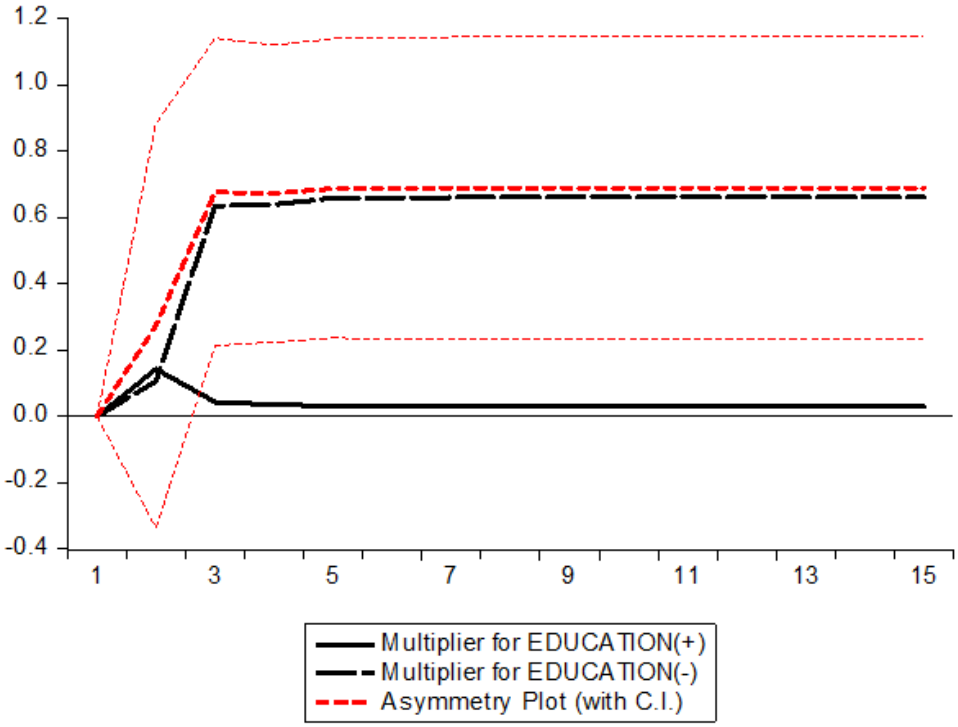

Figure 1

Asymmetric cumulative effect of education on CO2 emission

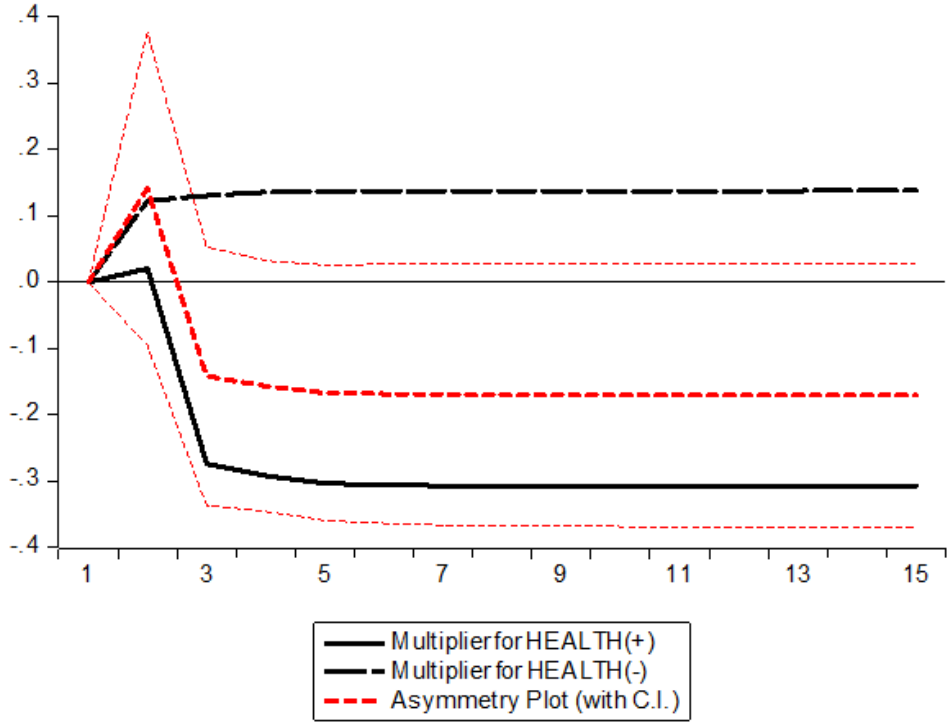

Figure 2

Asymmetric cumulative effect of health on CO2 emission

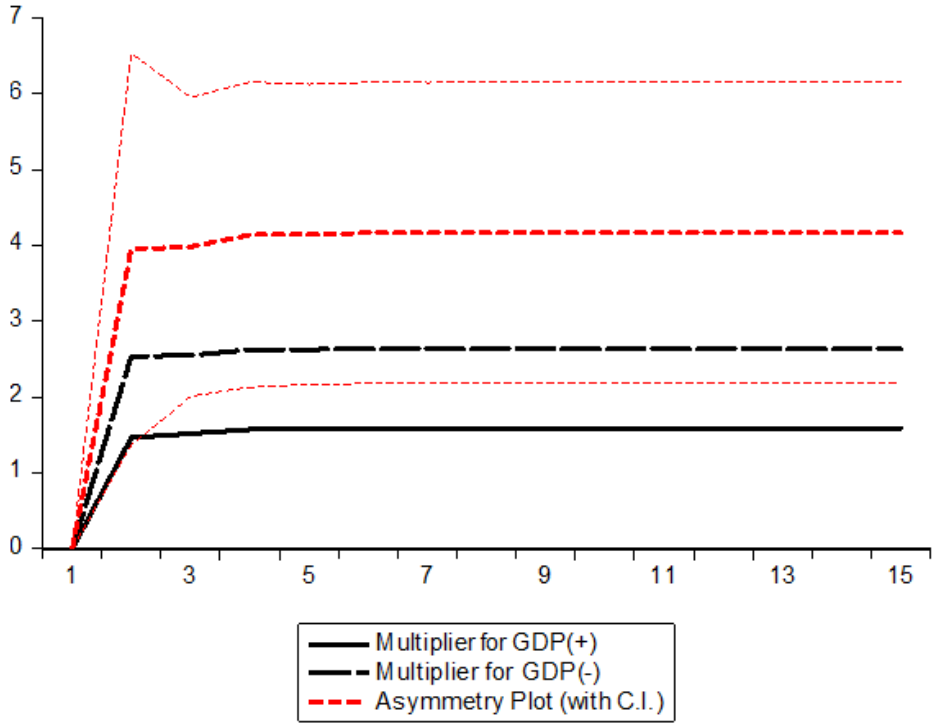

Figure 3

Asymmetric cumulative effect of GDP on CO2 emission