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The nexus between carbon emission, energy use, and health expenditure: empirical evidence from Bangladesh

Asif Raihan[1*], Sadia Farhana[2], Dewan Ahmed Muhtasim[3], Md Ahsan Ul Hasan[3], Arindrajit Paul[3] and Omar Faruk[3]

Abstract

Bangladesh is facing a conundrum in figuring out how to improve public health while simultaneously reducing the environmental pollution. To alleviate the pressure from the high healthcare expenditure in Bangladesh, environmental management efforts to improve the quality of the environment need to be developed with the help of understanding the nexus between carbon emission, energy use, and health expenditure. In a society that is experiencing quick and difficult environmental problems due to rising energy demand, the current study focused on evaluating the effects of carbon dioxide emissions, fossil fuel energy use, and renewable energy use on health expenditure in Bangladesh. Time series data were analyzed from the year 2000 to 2020 using the Dynamic Ordinary Least Squares technique. The findings revealed that a 1% increase in carbon dioxide emissions and fossil fuel energy use will increase health expenditure by 0.95% and 2.67%, respectively. Furthermore, a 1% increase in renewable energy use may result in reduced health expenditure by 1.44% in the long run. This article provides policy recommendations to ensure environmental sustainability and healthcare facilities by lowering carbon emission in Bangladesh. This research would be helpful for designing a proactive health scheme to counteract the emerging health consequences of environmental pollution in Bangladesh.

Highlights

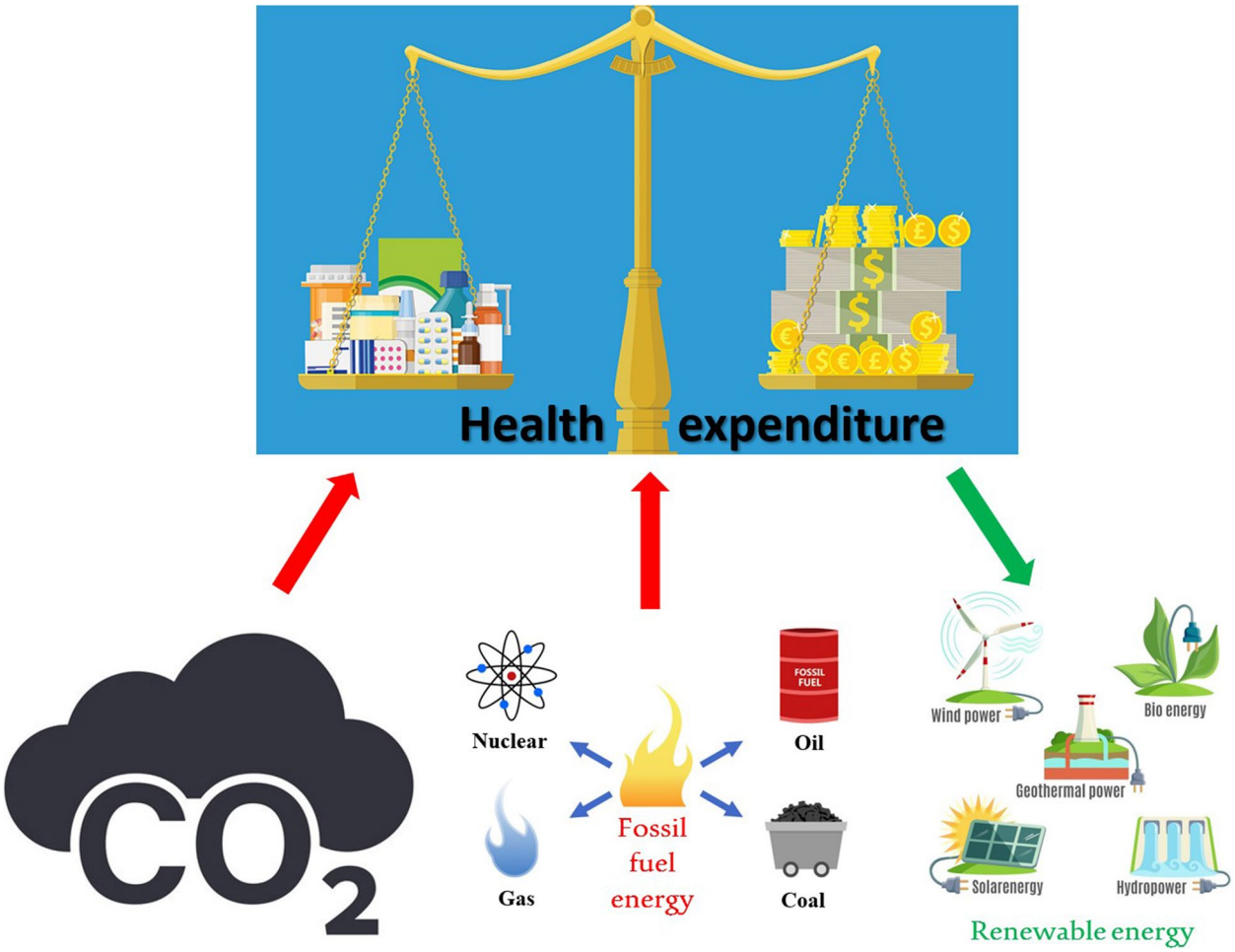
- Improving environmental quality and securing public health are critical for Bangladesh.
- This study estimated the effects of carbon emission and energy use on health expenditure in Bangladesh.
- Dynamic Ordinary Least Squares method was employed by utilizing time series data.
- The results provide new insights into the potential of renewable energy to reduce health expenditure.
- This article provides recommendations to improve environmental quality and ensure health security.

Keywords: Environment, Health, CO_2 emissions, Climate change, Sustainability, Renewable energy

*Correspondence: asifraihan666@gmail.com

[1] Institute of Climate Change, Universiti Kebangsaan Malaysia, 43600 Bangi, Malaysia
Full list of author information is available at the end of the article

Graphical Abstract



1 Introduction

Greenhouse gas (GHG) emissions, exclusively carbon dioxide (CO_2) from the utilization of fossil fuels and deforestation, have ended up causing the earth's temperature to rise and its climate to shift dramatically over the course of the 21st century (Ahiduzzaman and Islam 2011; Jaafar et al. 2020; Sahoo et al. 2021; Raihan et al. 2021a; Raihan et al. 2022a). Prolonged in CO_2 emissions are predicted to have catastrophic effects on the earth's climate and disastrous consequences on society and human health (Raihan et al. 2018; Raihan et al. 2019; Raihan et al. 2021b; Isfat and Raihan 2022; Islam et al. 2022; Raihan and Said 2022). Global health expenditures had increased by approximately USD100 billion from 2016 to 2017, while, among this expenditure, 40% was private and the rest was public (Anwar et al. 2021). Healthcare costs attributable to pollution account for about 5% of GDP in developing countries. This means that rising healthcare costs might undermine efforts to provide healthcare to all people (Xiu et al. 2022). Several countries are realizing the importance of adjusting their healthcare systems to address the rising health risks associated with environmental degradation (Xiu et al. 2022). The rising cost of healthcare is a major drain on the economies of developing nations like Bangladesh, and many others who want to improve its healthcare system. Bangladesh has one of the uppermost pollution rates in the globe, and because of its rapid population increase, its environment is deteriorating dramatically (Dulal et al. 2021). Bangladesh's CO_2 emissions per capita in 2019 were over 0.6 metric tons, a roughly 3-fold increase from the CO_2 emission level in 2000 (Murshed et al. 2021). Consistent with the Global Climate Risk Index 2021, Bangladesh is one of the seven countries most vulnerable to climate change, which threatens economic stability and public health. In order to ensure sustainable growth and health security,

improving environmental conditions through emission reduction and climate change mitigation have become key priorities (Villanthenkodath et al. 2021; Raihan and Tuspekova 2022a; Sahoo and Sahoo 2022).

Moreover, the United Nations announced Sustainable Development Goals (SDGs) to be accomplished by 2030, with one of the primary aims being improving health and well-being, as well as providing inexpensive and clean energy, pure water, and sanitation to enhance people's health regardless of where they reside (Goal-3, 6 and 7). However, it is acknowledged that health has a significant impact on long-term growth beyond national boundaries and socioeconomic status. Quick action is necessary for developing economies with a high population growth rate to improve people's living conditions (Anwar et al. 2021). More people living in the world means more strain on natural resources like trees, dirt, air, and water. Furthermore, this indicates that higher levels of air pollution induce an increase in the prevalence of infectious diseases such as malaria, TB, cholera, and dengue fever, and hence, higher healthcare costs (Anwar et al. 2021). Nevertheless, health is among the most critical elements in determining the quality of life, and CO_2 emission has an impact on public healthcare. Headaches, drowsiness, anxiousness, tingling or pins and needles senses, trouble breathing, sweating, fatigue, rapid heart rate, rising blood pressure, coma, asphyxiation, and convulsions are all possible side effects of prolonged CO_2 exposure. The most serious illnesses brought on by CO_2 emissions are bronchitis, chronic obstructive pulmonary disease (COPD), allergic rhinitis, and infections of the lungs. Additionally, a decline in residents' health may result in a rise in residents' healthcare costs (Hao et al. 2018). As a result, academics and policymakers have paid close attention to the link between the poor condition of the natural environment and health expenditures.

Over the past few decades, the interaction between environmental degradation and health expenditure has become a topic of increasing importance in the literature for both developing and developed countries. Bangladesh is one of the fastest-growing emerging economies in the world (Gupta et al. 2022). Bangladesh's economy is greatly dependent on the fossil-fuel-based energy industry, infrastructure, and transportation, resulting in massive fossil-fuel energy use. The quest for economic advancement has resulted in increased air pollution and hazardous waste production which are detrimental to human health (Xiu et al. 2022). In addition, Bangladesh's rapid urbanization and industrialization increase fossil fuel energy consumption which leads to environmental deterioration and health risks (Ali et al. 2022; Raihan et al. 2022b; Rout et al. 2022). Furthermore, as worries about energy crises, global warming, environmental degradation, and public health risks have increased, so has the worth of renewable energy (Sohag et al. 2021; Raihan et al. 2022c). The world's economy is increasingly transitioning to renewable energy sources as fossil fuel reserves dwindle (Raihan and Tuspekova 2022b; Raihan et al. 2022d) and their detrimental environmental and public health consequences become more apparent. Conventional energy use can be reduced while long-term global economic production, environmental quality, and public health are protected by using renewable energy (Raihan and Tuspekova 2022c). Bangladesh has a wealth of renewable resources for electricity and has institutionalized policies to promote the development of this sector (Islam et al. 2014). Despite this, there is a lack of research performed in Bangladesh on the potential of renewable energy to improve public health by increasing the quality of the environment.

However, health problems and healthcare costs are on the rise in many industrialized and emerging economies. Consequently, it is of the utmost importance to pinpoint the causes of health issues that can influence people, so that countermeasures can be implemented to safeguard human progress. CO_2 emissions and usage of fossil fuel energy sources are known to contribute significantly to health problems and are found to drive health expenditure increases. Despite the growing interest in this topic among academics around the world, very few studies have used econometric techniques to scrutinise the nexus between CO_2 emissions, energy use, and health expenditure, especially in Bangladesh which is facing conundrum in figuring out how to improve public health while simultaneously reducing the environmental pollution. There is a research gap in the current literature on the nexus between pollution and health expenditure, which is crucial for a developing nation like Bangladesh to design a proactive health scheme to counteract the emerging health consequences of pollution. In order to alleviate the pressure from the high healthcare expenditure in Bangladesh, environmental management efforts to provide clean, healthy air would be developed with the help of understanding the relationship between environmental degradation and expenditure on health. The legislators should recognize this if the country pursues to strike a balance among environmental degradation, public health security, climate change mitigation, and sustainable development. Thus, the current study filled up the research gap in the current literature by evaluating the effects of CO_2 emissions, fossil fuel energy use, and renewable energy use on health expenditure in Bangladesh.

This study is important since it makes a contribution to recent research as well as the policymaking process in Bangladesh in a number of different aspects. First, this research contributes fresh insights into the existing academic literature on the nexus between carbon emission, energy use, and health expenditure in the case of

Bangladesh, so helping to close a research gap in the field by utilizing the Dynamic Ordinary Least Squares (DOLS) method. Second, the novel aspect of this study is the evaluation of the effects of the use of fossil fuel energy and renewable energy on health expenditures. This is a pioneering effort to uncover the nexus that exists between carbon emission, fossil fuel energy use, renewable energy use, and health expenditures. The current study examined the financial implications of using both fossil fuels and renewable energy sources, with the goal of comparing the relative importance of these factors in determining healthcare costs in Bangladesh. Third, in order to validate the accuracy of the findings, numerous unit root tests in addition to diagnostic tests were carried out. Fourth, for the purpose of determining whether or not there was a causal connection between the variables, the paired Granger causality test was carried out. Lastly, the outcomes of the study would offer policymakers the knowledge that is both relatively complete and valuable for the development of effective policies in the areas of emission reduction and enhancement of healthcare services in Bangladesh. Additionally, the results from this scrutiny are helpful for evaluating environmental policy and forming further policy in order to prepare Bangladesh for a world with a temperature increase of 1.5 degrees Celsius. This will be accomplished by strengthening policy and action plans to reduce the negative effects of climate change, which will, in turn, ensure long-term sustainable development, public health security, and environmental quality. The findings of this study may be used to offer recommendations to other developing nations that are looking to establish effective measures to reduce climate-related health hazards while simultaneously increasing their climate change adaptation and mitigation policies.

2 Methods

2.1 Data

This research carried out an empirical study of the influences of CO_2 emissions, fossil fuel energy use, and renewable energy use on health expenditure in Bangladesh using the DOLS tactic of cointegration proposed by Stock and Watson (1993). Because of its ability to characterize an incessant response capricious as a role of one or more forecaster variables, the DOLS linear model was utilized for this research. It is also useful for analyzing experimental, monetary, and environmental data, as well as for understanding and predicting the behavior of complex systems (Raihan and Tuspekova 2022d). Bangladesh's time series data for the year 2000 to 2020 were obtained from the World Development Indicator (WDI) dataset. In this investigation, health expenditure was used as the dependent variable, while CO_2 emissions, fossil fuel energy use, and renewable energy use were the independent variables. In order to ensure normally distributed data, the variables have been log-transformed. Table 1 lists the variables, their logarithms, the units of measurement, and the data sources used.

2.2 Theoretical framework

Theoretically, higher healthcare costs are related to deteriorating environmental conditions, such as polluted air, which may be traced back to emissions of carbon dioxide and an increased reliance on energy derived from fossil fuels. However, lowering emissions from fossil fuel energy sources can be accomplished by increasing the percentage of renewable energy in the total final energy usage (Sohag et al. 2019; Sharif et al. 2021). This will contribute to the improvements in both environmental quality and public health. By utilizing the following equation, which has been developed within the framework of the standard Marshallian demand (Friedman 1949) function at time t, the purpose of this study was to estimate the effect that CO_2 emissions, use of fossil fuel energy, and use of renewable energy have on health expenditures.

$$HE_t = f(CO_{2t}; FFE_t; RNE_t) \quad (1)$$

where HE_t is the health expenditure at time t, CO_{2t} is the CO_2 emissions at time t, FFE_t is the fossil fuel energy use at time t, and RNE_t is the renewable energy use at time t.

2.3 Econometric model

The Eq. (2) portrays the econometric model:

$$HE_t = \tau_0 + \tau_1 CO_{2t} + \tau_2 FFE_t + \tau_3 RNE_t + \varepsilon_t \quad (2)$$

Table 1 Variables, the units of measurement, and the data sources

Variables	Description	Logarithmic forms	Units	Sources
HE	Health expenditure	LHE	Health expenditure (percentage of GDP)	WDI
CO_2	CO_2 emissions	LCO_2	Kilotons (kt)	WDI
FFE	Fossil fuel energy use	LFFE	Percentage of total final energy use	WDI
RNE	Renewable energy use	LRNE	Percentage of total final energy use	WDI

where τ_0 and ε_t stand for the intercept and the error term, respectively. Additionally, τ_1, τ_2, and τ_3 denote the coefficients.

Furthermore, Eq. (2) can be arranged logarithmically as follows:

$$LHE_t = \tau_0 + \tau_1 LCO_{2t} + \tau_2 LFFE_t + \tau_3 LRNE_t + \varepsilon_t \quad (3)$$

2.4 Methods for determining data stationarity

The unit root test is essential for forestalling the occurrence of false regression. It confirms that the series are stationary and then evaluations of the regression equation employing procedures that are stationary (Raihan and Tuspekova 2022e). Before the investigation of the topic of cointegration, the empirical data indicates the need of laying the groundwork for the integration procedure (Raihan and Tuspekova 2022f). As a result of the fact that the efficiency of unit root tests varies depending on the size of the sample, various studies recommend conducting numerous unit root tests in order to evaluate the series integration categorization (Raihan and Tuspekova 2022g). This study utilized the Augmented Dickey-Fuller (ADF) test proposed by Dickey and Fuller (1979), the Dickey-Fuller generalized least squares (DF-GLS) test created by Elliott et al. (1992), and the Phillips-Perron (P-P) test suggested by Phillips and Perron (1988) to find the autoregressive unit root. In this particular study, the unit root test was applied to guarantee that no variable surpassed the instruction of integration and to provide justification for the utilization of the DOLS methodology rather than the more conventional ways of cointegration.

2.5 The DOLS cointegration regression

DOLS, a refined form of the ordinary least squares estimate (OLS), was utilized in the study examining the time series data. Explanatory variables, in addition to the leads and lags of their baseline differential terms, were integrated as part of the DOLS cointegration test. This was done in order to control endogeneity and compute standard deviations. This was achieved by employing a covariance matrix of errors that was unquestionably resistant to serial correlation (Raihan and Tuspekova 2022h). Evidence that the error term has been orthogonalized may be seen in the fact that both the leading and trailing terms of the various terms are accounted for in the analysis. This test for assessing whether or not the variables have statistical significance can be relied upon because the standard deviations of the DOLS estimator follow a normal asymptotic distribution (Raihan and Tuspekova 2022i). When there is a mixed order of integration, the DOLS approach is an efficient method that enables the individual variables in the cointegrated outline to be integrated. The estimation of the dependent variable on the explanatory factors in levels, leads, and lags is how this is carried out (Raihan and Tuspekova 2022j).

The key advantage of the DOLS estimate method is the inclusion of mixed-order integration of individual variables within the cointegrated outline. For example, in the DOLS estimation method, one of the I(1) variables was regressed against other variables. Some of these other variables were also I(1) variables with leads (p) and lags (−p) of the first difference, while others were I(0) variables with a constant term. All of these variables were compared to the I(1) variable that was being regressed against them. Several of the variables in the I(1) set have both leads (p) and lags (−p) of the initial difference (Begum et al. 2020). As a result of pooling the leads and lags among the explanatory components, this estimation eliminates the issues of small sample bias, endogeneity, and autocorrelation that constantly occur in previous attempts to estimate (Raihan and Tuspekova 2022k). After ensuring that the study's parameters were cointegrated, the investigation used Eq. (4) to conduct the DOLS test to estimate the long-run coefficient:

$$\Delta LHE_t = \tau_0 + \tau_1 LHE_{t-1} + \tau_2 LCO_{2t-1} + \tau_3 LFFE_{t-1} + \tau_4 LRNE_{t-1} + \sum_{i=1}^{q} \gamma_1 \Delta LHE_{t-i} + \sum_{i=1}^{q} \gamma_2 \Delta LCO_{2t-i} + \sum_{i=1}^{q} \gamma_3 \Delta LFFE_{t-i} + \sum_{i=1}^{q} \gamma_4 \Delta LRNE_{t-i} + +\varepsilon_t \quad (4)$$

where Δ is the first difference operator and q is the optimum lag length in Eq. (4).

2.6 Pairwise Granger causality analysis

The purpose of this research was to investigate the potential causal connection between different factors. Therefore, the inquiry utilized the paired linear Granger-causality test that was developed by Granger (1969) in order to ascertain whether or not there was a causal relationship between the variables. Granger causality can be described as a "statistical concept of causation based on prediction." As a result of the numerous benefits that Granger causality offers in comparison to other time-series evaluation methodologies, it was chosen to be utilized in the current investigation. It is supposed that one time series, Y, "Granger-causes" another time series, X, when Y is able to assist in the prediction of the future of

X by making use of another time series, X. This is what the term "Granger-causes" means. The time series for these two variables has a length of data called T, and the numbers X_t and Y_t (t = 1, 2,....., T) suggest those variables' corresponding values at time t. A bivariate autoregressive model can be employed to models X_t and Y_t utilizing the following equations:

$$X_t = \beta_1 + \sum_{i=1}^{n} \alpha_i Y_{t-i} + \sum_{i=1}^{n} \mu_i X_{t-1} + e_t \quad (5)$$

$$Y_t = \beta_2 + \sum_{i=1}^{n} \Omega_i Y_{t-1} + \sum_{i=1}^{n} \infty_i X_{t-i} + u_t \quad (6)$$

where n represents the number of lags, as specified by the information criteria β_1, β_2, α_i, Ω_i, μ_i, and ∞_i as parameters for evaluation; and e_t and u_t are residual terms.

Estimating the coefficients can be done by the use of the method of ordinary least squares, and F tests can be carried out to figure out whether or not there is Granger causality between X and Y.

3 Results

3.1 Summary statistics

The outcomes of the variable-level summary procedures are displayed in Table 2. Each variable had 21 samples from Bangladesh's annual data from 2000 to 2020.

3.2 Unit root test outcomes

Unit root tests were employed to illustrate that the DOLS approach was preferable to utilizing merely cointegration. This was done by ensuring that no variable exceeded the order of integration, which was achieved through the use of the unit root test. Table 3 shows the outcomes of testing unit roots using the ADF, DF-GLS, and P-P tests. Results from all three unit root tests showed that LHE, LFFE, and LRNE were initially non-stationary at levels but subsequently became stationary at the first difference. The DF-GLS test found LCO2 to be non-stationary at the level but stationary at the first difference, while the ADF and P-P tests showed that LCO2 was stationary at the level and remained stationary after taking the first difference. The variables were stationary at the merged levels according to both level and first-order integration tests, indicating that the DOLS method was superior to the more conventional cointegration analysis.

3.3 The outcomes of the DOLS

The results of the DOLS estimation are shown in Table 4. The anticipated long-run coefficient of LCO2 was positive and significant at a 1% level, which suggested that a 1% rise in CO_2 emissions would result in a 0.95% increase in health expenditure in Bangladesh when all other factors were held constant. Additionally, the calculated long-run coefficient of LFFE was positive and significant at a 1% level, which demonstrated that an increase of 1% in the usage of fossil fuel energy was associated with an increase of 2.67% in health expenditures in Bangladesh. Furthermore, the calculated coefficient of LRNE was negative and significant at a level of 5%, which indicated that

Table 2 Summary statistics of the variables

Variables	LHE	LCO2	LFFE	LRNE
Mean	0.90918	10.7699	3.72589	3.72297
Median	0.91167	10.8313	3.71539	3.71539
Maximum	1.01566	11.3617	4.07791	4.07791
Minimum	0.72453	9.98276	3.35006	3.29691
Std. Dev.	0.08231	0.43731	0.22772	0.23301
Observations	21	21	21	21

Table 4 DOLS results: LHE is a dependent variable

Variables	Coefficient	Standard error	t-Statistic	*p*-value
LCO2	0.945787***	0.178361	5.302661	0.0001
LFFE	2.672283***	0.778908	3.430807	0.0032
LRNE	−1.436484**	0.507806	−2.828803	0.0116
C	15.20245	3.181868	4.777837	0.1171
R^2	0.861102			
Adjusted R^2	0.822931			

The levels of significance indicated by ***, **, and * are as follows: 1%, 5%, and 10%, respectively

Table 3 Outcomes of unit root testing

Logarithmic form of the variables	ADF		DF-GLS		P-P	
	Log levels	Log first difference	Log levels	Log first difference	Log levels	Log first difference
LHE	−2.17574	−3.30058**	−1.34725	−3.43848***	−2.18894	−3.30058**
LCO2	−2.48889**	−5.16377***	−1.08422	−3.50558***	−2.63683**	−5.12724***
LFFE	−0.01856	−4.93771***	−0.18514	−5.10755***	0.04076	−4.93589***
LRNE	1.25328	−4.12569***	0.54709	−3.99058***	1.84269	−4.12569***

The levels of significance indicated by ***, **, and * are as follows: 1%, 5%, and 10%, respectively

an increase in the use of renewable energy in Bangladesh of 1% was related with a reduction in the country's long-term health expenditures of 1.44%. The outcome indicated that CO_2 emissions and increased use of fossil fuel energy were responsible for environmental damage in Bangladesh which was accountable for increased health expenditure. Furthermore, this study revealed the potential of renewable energy use to reduce health expenditure by improving the quality of environment in Bangladesh. Additionally, it is important to notice that the signs of the predicted coefficients were consistent from both a theoretical and a practical point of view. The R^2 value was 0.8611, and the adjusted R^2 value was 0.8229; these numbers showed that the regression model that was constructed fit the data extremely well. This meant that the independent variables might explain around 82% of the variance in the dependent variables' effect on the outcome.

3.4 Diagnostic inspection

The present research employed normality, heteroscedasticity, and serial correlation analyses to verify the significance of the cointegration valuation. Table 5 displays the results of the diagnostic examinations. The model's results showed no autocorrelation or heteroscedasticity, suggesting normality. To further verify the model's robustness, this study employed the cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals (CUSUMQ) tests. The CUSUM and CUSUMQ plots at the 5% level of significance are shown in Fig. 1. As the blue lines represent the residual values, the red lines represent the confidence intervals. The results showed that the values of the evaluated residuals continued to be within the limits of confidence at the 5% level of significance, proving the model's steadiness.

3.5 Results of pairwise Granger causality test

Granger causality was tested by using the F-statistic, and its presence was demonstrated by the presence of a significant correlation between the two variables in question. Table 6 presents the analysis of the pairwise Granger causality, which includes the direction of the causality between the variables. For example, unidirectional causality from left to right ($\rightarrow$) and unidirectional causality from right to left ($\leftarrow$) are both examples of unidirectional causality. However, no causality ($\neq$) indicates that there is no relationship between the variables. The findings of the pairwise Granger causality test pointed to the fact that LCO2 and LHE, LFFE and LHE, LFFE and LCO2, and LRNE and LCO2, displayed unidirectional causality due to statistical significance leading to the rejection of the null hypothesis. This clearly specifies that CO_2 emissions and fossil fuel energy use Granger-cause health expenditure; fossil fuel energy use Granger-cause CO_2 emissions; and CO_2 emissions Granger-cause renewable energy use. However, the present investigation found no causal relationship of renewable energy use with health expenditure and fossil fuel energy use.

4 Discussion

The present study examined how different environmental factors and health expenditures had evolved together in Bangladesh. The current research investigated the connection between health expenses and carbon emissions. The result revealed that increased CO_2 emissions caused a rise in health expenditure. The current study's conclusion that rising healthcare costs are correlated with rising CO2 emissions is backed up by Hao et al. (2018), Badulescu et al. (2019), Shahzad et al. (2020), Ullah et al. (2020), Anwar et al. (2021), Mujtaba and Ashfaq (2022), and Xiu et al. (2022). CO_2 emissions have an effect on people's health, which could lead to a rise in healthcare expenses. The long duration of medical therapy for many chronic illnesses, like long-term chronic diseases, may necessitate constant medical input, and this outcome partially represents the significance of medical expense. Therefore, medical expenditure has a remarkable amount of inertia. The results of the current study highlight the fact that health expenditures are continuing to climb as a result of increased carbon emissions and other ecologically related disorders brought on by emissions. Carbon emission has a negative influence on human health and is to blame for many potentially fatal disorders like bronchitis, heart issues, lung issues, and many others. In this notion, it is important to promote a green environment policy that guarantees a decrease in CO_2 emissions. The increased economic activity causes more pollution and climate change

Table 5 Diagnostic test outcomes

Diagnostic tests	Coefficient	*p*-value	Decision
Jarque-Bera test	1.021314	0.5291	Residuals are normally distributed
Lagrange Multiplier test	0.925218	0.4239	No serial correlation exits
Breusch-Pagan-Godfrey test	1.311967	0.1815	No heteroscedasticity exists

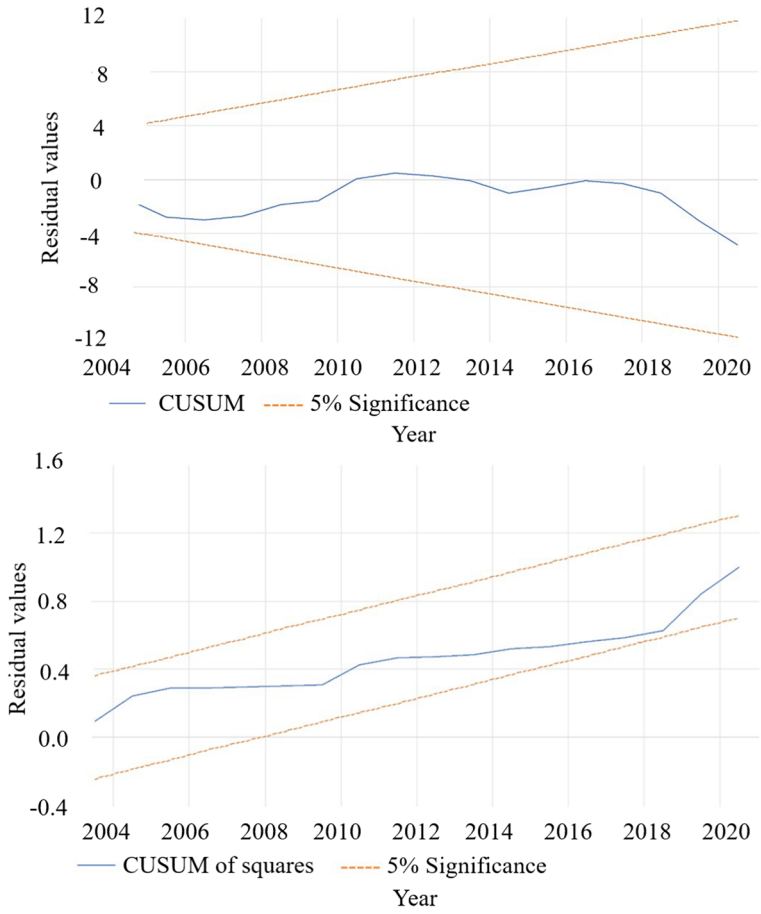


Fig. 1 The outcomes of CUSUM and CUSUMQ tests

Table 6 The outcomes of pairwise Granger causality analysis

Null hypothesis	F-statistic	Decision on N- hypothesis	Causality direction
LCO2 does not Granger cause LHE	7.1646***	Reject	LCO2 → LHE
LHE does not Granger cause LCO2	2.8115	Accept	
LFFE does not Granger cause LHE	8.9733***	Reject	LFFE → LHE
LHE does not Granger cause LFFE	0.3742	Accept	
LRNE does not Granger cause LHE	0.5327	Accept	LRNE ≠ LHE
LHE does not Granger cause LRNE	1.7623	Accept	
LFFE does not Granger cause LCO2	7.4291***	Reject	LFFE → LCO2
LCO2 does not Granger cause LFFE	0.3121	Accept	
LRNE does not Granger cause LCO2	0.1371	Accept	LRNE ← LCO2
LCO2 does not Granger cause LRNE	3.1152*	Reject	
LRNE does not Granger cause LFFE	2.3619	Accept	LRNE ≠ LFFE
LFFE does not Granger cause LRNE	0.3945	Accept	

The levels of significance indicated by ***, **, and * are as follows: 1%, 5%, and 10%, respectively

(Raihan et al. 2022e). Even when technical and compositional influences are taken into account, a greater standard of living is associated with a higher carbon footprint. Expenditures on healthcare, when adjusted for the scale effect, grow in tandem with one's income. Many nations have begun to incorporate the intensity of energy use, reflecting technical shifts that have resulted in decreasing emissions per capita, as a result of structural and technological shifts. Energy's intensity gradually declines over time as a result of structural and technical improvements. Collectively, these measures will bring about a further decrease in CO_2 emissions and healthcare expenditures.

The purpose of this research was to analyse the relationship between health care costs and energy use in Bangladesh. This study's findings highlight the costs associated with poor health due to a reliance on fossil fuels and the savings that may be realized by switching to renewable energy sources. Research indicates that using fossil fuels to generate electricity has a substantial and sizable effect on healthcare costs over the long term. The study's results suggest that rising fossil fuel consumption drives up healthcare costs in Bangladesh. The study's outcomes are consistent with those found in other research by credible sources like Jermsittiparsert's research (2021). It is not in the best interest of the environment or public health to rely on fossil fuels for energy production, urbanization, and industrialization in Bangladesh. Even though it is a developing nation, Bangladesh still uses coal, natural gas, and oil to generate power, which poses serious health hazards due to pollution (Raihan et al. 2022f; Raihan et al. 2022g). The study also looked into how switching to renewable energy sources affected healthcare costs in Bangladesh. Based on these results, increasing the portion of renewable energy in Bangladesh's overall energy mix could help the country cut healthcare costs. Results comparable to these were reported by Badulescu et al. (2019), Shahzad et al. (2020), Ullah et al. (2020), Jermsittiparsert (2021), and Mujtaba and Ashfaq (2022). To protect public health and slow down the rate of climate change, it is essential to use renewable energy sources for power generation.

Moreover, to reduce CO_2 emissions from the burning of fossil fuels for energy generation and industrial processes, the administration of Bangladesh can ratify laws related to high carbon taxes, carbon capture and storage, and emission trading initiatives. Additionally, encouraging the economic shift to renewable energy is crucial for dropping environmental bearings on health. More widespread adoption of renewable energy sources may have far-reaching implications for emissions reduction, improve public health, and facilitate industrial growth (Voumik et al. 2022). Renewable energy technologies should be encouraged and supported by decision-makers. By discouraging industrial, commercial, and domestic use of fossil fuels, Bangladesh could take strategies to lower the cost of renewable energy. Moreover, tax incentives, monetary aid, and administration contracts are all examples of monetary techniques that the administration may use to inspire people to make the shift to cleaner energy sources. In order to encourage the green living concept, which includes low-carbon lifestyle choices and consumer behavior, the administration may utilize the media.

The outcomes of the present study indicate that environmental quality has been demonstrated to be a contributing factor to an increase in health expenses; therefore, Bangladesh should establish measures and policies linked to environmental quality in order to lower the number of health disorders that occur in the country. To ensure better healthcare facilities, an adequate, adaptable, and inexpensive healthcare spending plan integrating public and private efforts is required. Increased public services investment may be a realistic way to lower the societal costs of environmental degradation. Establishing a considerable number of hospitals, providing a sufficient number of qualified doctors, nurses, and healthcare implants, and organizing modern healthcare services and better diagnosis equipment are all necessary to ensure better health. Simultaneously, the administration could monitor and assess the level of air pollutants and timely reveal information to the public about certain air quality levels, associated health risks, and solutions for minimizing exposure in an easy-to-understand manner. This study proposes that efforts to reduce environmental degradation should be increased by adopting carbon-free technical equipment, healthcare spending for people afflicted by declining environmental quality, and future strain on government resources. In addition, the energy needs of healthcare facilities, which are currently met with fossil fuels, might be met with renewable technology such as solar.

5 Conclusions

This study estimated the dynamic effects of CO_2 emissions, fossil fuel energy use, and renewable energy use on health expenditure in Bangladesh. The DOLS method was utilized, and time series data for the years 2000–2020 were used in the analysis. During the course of this investigation, the ADF, DF-GLS, and P-P unit root tests were utilized in order to determine the integration order of the dataset. The empirical results showed that a 1% increase in CO_2 emissions and fossil fuel energy use will increase health expenditure by 0.95% and 2.67%, respectively. Furthermore, a 1% increase in renewable energy use may result in reduced health expenditure by 1.44%

in the long run. The result indicates that declining environmental quality causes rising health expenditures. The findings are insightful about the potential for renewable energy usage to reduce health expenditure by improving the environmental condition in Bangladesh. The study provides legislators with more inclusive and beneficial knowledge for evolving effective strategies in the areas of emission reduction and improvement of healthcare services in Bangladesh.

Although the present analysis yielded extensive empirical results in the case of Bangladesh, the assessment had some flaws to avoid in future studies. One of the vital shortcomings of the assessment was the unavailability of data on health expenditure ahead of the phase of analysis, which restricted the strength of the econometric methods utilized. Future studies may look into other factors that could contribute to lowering health expenditure and improving public health by increasing ecological sustainability, such as recycling commodities, waste management, forestation, and technological innovation. This investigation used CO_2 levels as a proxy for air pollution. Methane (CH_4), nitrous oxide (N_2O), sulfur dioxide (SO_2), and short-lived climate forces (SLCF) are just some of the other air-polluting indicators that need more study in addition to consumption-based CO_2 emission. Future research may look into additional indicators of pollution, for instance, water and land pollution, and the health effects they have.

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Authors' contributions
AR, SF, and DAM contributed to the study's conception and design. Material preparation, data collection, and analysis were performed by AR, MAUH, and OF. The first draft of the manuscript was written by AR and AP commented on previous versions of the manuscript. Both authors read and approved the final manuscript.

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Availability of data and materials
All data generated or analyzed during this study are available here: https://databank.worldbank.org/source/world-development-indicators.

Declarations

Ethics approval and consent to participate
Not applicable.

Competing interests
All the authors associated with this work declare that there is no conflict of interest.

Author details
[1]Institute of Climate Change, Universiti Kebangsaan Malaysia, 43600 Bangi, Malaysia. [2]School of Medical Sciences, Universiti Sains Malaysia, 16150 Kubang Kerian, Kelantan, Malaysia. [3]Faculty of Information Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Malaysia.

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