# Impact of Rapid Economic Development with Rising Carbon Emissions on Public Health and Healthcare Costs in Bangladesh

Md Fokhrul Islam[1], Shusmoy Debnath[2], Himal Das[3], Fuad Hasan[4], Sanjida Sultana[5], Rubel Datta[6], Bilash Mallik[7], Md. Halimuzzaman[8]

## Abstract

Background: Bangladesh, a rapidly developing country, is experiencing a critical phase where economic growth and environmental sustainability must be balanced. The swift industrialization and urbanization have led to increased energy consumption and carbon emissions, negatively impacting public health and healthcare expenditures. This study determined the intricate relationships between healthcare expenditure and its determinants—economic growth, $CO_2$ emissions, urbanization, and natural resource use—in Bangladesh. Methods: Utilizing a dataset from 2004 to 2023, this study applies advanced econometric methods, including the dual adjustment approach, spectral causality, fully modified ordinary least squares (FMOLS), dynamic ordinary least squares (DOLS), and canonical cointegrating regression (CCR). Results: Results demonstrate a significant positive correlation between economic growth, urbanization, natural resources, and $CO_2$ emissions on healthcare spending. The findings underscore that $CO_2$ emissions and urbanization are substantial contributors to rising healthcare costs, while natural resources and economic growth present varying impacts based on different econometric models. The dual adjustment approach provides robust evidence of cointegration, revealing the long-term interactions among these variables. Conclusion: In conclusion, the study emphasizes the urgent need for effective national policies to mitigate healthcare costs driven by environmental degradation and economic growth. By understanding these relationships, policymakers can better manage health expenditures while promoting sustainable development in Bangladesh. The research highlights the necessity of integrating environmental and health policies to achieve a balanced growth trajectory.

**Keywords:** Healthcare Expenditure, Economic Growth, Carbon Emissions, Urbanization, Natural Resources

***Significance*** | This study showed how economic growth, $CO_2$ emissions, urbanization, and natural resource use impact healthcare spending in Bangladesh, offering insights for policy development.

*Correspondence. Md Fokhrul Islam, School of Politics, Public Affairs, and International Studies (SPPAIS), University of Wyoming, USA.
Email: fokhrulislam2909@gmail.com, ORCID ID: 0000-0002-0647-2813

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## Introduction

Bangladesh, a country known for its rapid growth and resilience, is at a critical juncture in balancing economic development and environmental sustainability. Rapid industrialization and urbanization affect the country's economic landscape, causing significant shifts in a variety of areas, including healthcare. However, this rising trend raises concerns, particularly about carbon emissions and the larger consequences for public health and healthcare spending. The pursuit of economic growth fueled by

**Author Affiliation.**
[1] School of Politics, Public Affairs, and International Studies (SPPAIS), University of Wyoming, USA.
[2]Department of Economics, University of Dhaka, Bangladesh.
[3]Department of Economic, University of Dhaka, Bangladesh.
[4]Department of Economics, University of Dhaka, Bangladesh.
[5]Department of Environmental Science, Khulna University, Bangladesh.
[6]Department of Risk Control & Safety Management, University of Wisconsin-Stout, USA.
[7]Department of Sociology, Govt. Brojomohun College, Bangladesh.
[8]School of Business, Galgotias University, Greater Noida, Uttar Pradesh, India.

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significant energy consumption has resulted in an increase in air pollution, posing a threat to human well-being (Timmons Roberts et al., 2003). Economic development in Bangladesh has helped to raise living standards, reduce poverty, and improve access to basic services. Over the last few decades, the country has made significant growth in industries such as manufacturing, services, and technology. This economic explosion, although supporting greater income levels and infrastructure developments, leads to increased energy consumption and higher carbon emissions (Abid et al., 2020). The interplay of these elements warrants a closer look at their impact on healthcare spending. Several countries emphasize the significance of developing an adaptable healthcare system to handle the growing health issues caused by environmental degradation. Emerging countries like Bangladesh seek to create a robust healthcare system; nevertheless, growing healthcare expenditures have a considerable influence on their GDP (Alleyne et al., 2013). As a consequence, Hussain et al. (2020) emphasized that the rapid increase in health costs is outpacing GDP growth in many economies, particularly in emerging markets. As per the United Nations Environment Programme (UNEP, 2016) developing countries invest around 5% of their GDP to health-related costs due from pollution. Consequently, the goal of having universal healthcare coverage is increasing day by day (Desha et al., 2010). Bangladesh's per capita health expenditure has risen dramatically over the years, from less than USD110 in 2004 to more than US$800 in 2023, as shown in Figure 1. Since 1978, Bangladesh has seen a fast increase in both per capita and overall health spending. In 1978, overall health expenditure accounted for roughly 3% of GDP. By the 1990s, it had risen to around 4% (World Bank, 2021). Since the start of Bangladesh's healthcare reform in 2013-23, the rate has increased significantly to 12%. In the field of empirical studies, a number of factors, including income, energy consumption, $CO_2$ emissions, population size, economic advancement, and individuals' well-being status, among others, have the ability to effect healthcare expenditure across diverse countries (Ifada & Jaffar, 2023). For instance, a study by Chaabouni et al. (2016) investigated the determinants of health spending in 51 nations, discovering that an increase in GDP contributes to healthcare costs. Similarly, the investigation by Azimi & Rahman (2024) examined the factors of healthcare cost using the STIRPAT framework from 1995 to 2018. Using AMG and CCEMG techniques, the researchers discovered that factors such as urbanization, industrialization, environmental impact, and economic expansion tend to increase health expenditures, whereas globalization reduces healthcare expenses. Additionally, a study conducted by Jahanger et al., (2023) utilized the PMG, panel causality, and DOLS techniques to analyze the drivers of healthcare expenditure in developing nations. The results of their analysis highlighted that natural resources, urbanization, economic advancement, and $CO_2$ emissions contribute to the rise in healthcare spending. Furthermore, a reciprocal causal relationship was noted between economic growth and health expenditure (Luby et al., 2015). The current literature in this field provides limited insights into the factors that influence healthcare spending, such as income levels, urban growth, natural resource consumption, and carbon dioxide emissions. As a result, this study intends to analyze the complicated connection between health expenditure and its determinants—namely, economic growth, $CO_2$ emissions, urbanization, and natural resource utilization—in the context of Bangladesh, the world's most populated nation (Wang et al., 2023). Examining the interrelationships between these variables in Bangladesh has become particularly important from a policy standpoint. Healthcare costs and societal misery are expected to rise in the absence of effective national policies, underscoring the critical need for this study. Furthermore, the health concerns caused by the exploitation of natural resources, coming from the dumping of numerous substances at mining sites, have not received adequate attention in terms of public health. The current study distinguishes itself by offering a robust examination of the collective influence of economic growth, urbanization, natural resources, and $CO_2$ emissions on healthcare expenditure in Bangladesh using advanced econometric approaches such as the dual adjustment approach (Crowley & Physicians, 2016). The dual adjustment methodology's key innovation is that it provides an alternate way to cointegration analysis by reducing the implicit assumption of solitary adjustment in such analyses. In addition, we used spectral causality, fully modified ordinary least squares (FMOLS), dynamic ordinary least squares (DOLS), and canonical cointegrating regression (CCR) estimators to assess these relationships.

**Literature Review**

Health expenditure includes diverse costs linked with healthcare services, nutritional programs, emergency health-related help, and family planning initiatives, but excludes sanitation and access to safe drinking water. Policymakers and researchers are increasingly focused on the variables influencing healthcare spending in both developing and developed countries, including rising environmental pollution, disease transmission, income inequities, and urban overpopulation. Numerous studies by (Crowley & Physicians*, 2016; Jahanger et al., 2023; Raihan, 2023) have investigated the determinants of health expenditure, yielding varied outcomes. For example, a study by Azimi & Rahman, (2024) Using data from 1995 to 2013, we studied health spending determinants across 51 countries using GMM estimator and panel causality methods. The results show that an increase in $CO_2$ levels adds to healthcare costs in these nations. Furthermore, the study conducted by (Cai et al., 2021) examined the relationship between health expenditure, GDP, and $CO_2$ emissions in Bangladesh and India

using data spanning from 1960 to 2019 and the GMM estimator. Their findings revealed a strong interconnection among $CO_2$ emissions, GDP, and health expenditure. The empirical analysis for both countries indicated that $CO_2$ emissions have a significant positive impact on health spending, whereas economic growth has a negative effect on health expenditure over the study period. Furthermore, no significant relationship was identified between urbanization and health expenditure in India, whereas urbanization had a beneficial influence on health expenditures in Bangladesh. Similarly, Islam & Jashimuddin, (2017) investigated the asymmetric relationship between $CO_2$ emissions and health expenditure in Bangladesh from 1990 to 2019, highlighting that a positive (negative) shock in $CO_2$ emissions positively (negatively) affect health expenditure. In a separate study by Azam et al., (2016) analyzed the determinants of healthcare expenditure among the top 10 nations with the highest healthcare expenditures using the STIRPAT framework from 1995 to 2018. The researchers used the AMG and CCEMG methodologies to investigate this link, demonstrating that urbanization, industrialization, environmental imprint, and economic growth all have a positive impact on healthcare expenses, but globalization acts as a mitigating factor. Several research studies have integrated natural resources into their models to analyze the determinants of healthcare spending. For instance, by utilizing data spanning from 2004 to 2022. Ferdous Khan, (2017) employed the PMG, panel causality, and DOLS methodologies to evaluate the factors influencing healthcare expenditure in developing countries. Their findings indicated that healthcare spending is influenced by natural resources, urbanization, economic growth, and an increase in $CO_2$ levels. Furthermore, there exists a bidirectional causal relationship between economic growth and healthcare expenditure. Similarly, Azam et al., (2016)conducted a study on OPEC nations examining the connection between healthcare spending and natural resources, using data from 2002 to 2015 along with panel OLS analysis, and discovered that natural resources have a positive impact on healthcare expenditure. Likewise, Khan et al., (2020) investigated the long-term relationship among $CO_2$ emissions, economic growth, and health expenditure across 18 OECD countries by employing data from 1975 to 2017 and bootstrap ARDL methodology. Additionally, the researchers identified a feedback loop between healthcare spending and $CO_2$ emissions specifically in New Zealand and Norway. Based on the summarized studies above, there is a lack of consensus regarding the influence of economic growth, urbanization, natural resources, and $CO_2$ emissions on healthcare expenditure. Consequently, the present study distinguishes itself by providing a robust examination of the collective impact of economic growth, urbanization, natural resources, and $CO_2$ emissions on healthcare expenditure in Bangladesh within the framework of advanced econometric methodologies such as the dual adjustment approach. The primary novelty of this technique lies in its ability to present an alternative for cointegration analysis by mitigating the implicit assumption of a singular adjustment (Farooq et al., 2019). Moreover, we employed spectral causality, DOLS, CCR, and FMOLS approaches to evaluate these interrelationships. Exploring the amalgamation of different methodologies serves to unveil the uniqueness of the techniques, yielding dependable estimations that support informed policy-making.

## Methods and Martials

In this study, we evaluate the influence of economic growth (GDP) on healthcare spending (HE) in Bangladesh. Various factors affecting health expenditure (HE), including urbanization (URB), carbon emissions ($CO_2$), and natural resources (NRR), are taken into account. The dataset employed in the study covers the period from 2004Q1 to 2023Q4, comprising 76 observations. The dependent variable examined is healthcare expenditure, which is defined as domestic general government health expenditure (% of GDP). The independent variables consist of GDP per capita (constant US$ 2010) for economic growth, total natural resources rents (% of GDP) for natural resources, metric tons per capita for $CO_2$ emissions, and Urban population (% of total population) for urbanization. Data for $CO_2$, HE, GDP, NRR, and URB are sourced from the World Bank database. The present study seeks to assess the long-term impact of economic growth, carbon dioxide emissions, natural resources, and urbanization on healthcare spending in Bangladesh. It is imperative to first ascertain the stationary characteristics of the variables under investigation prior to analyzing their long-term relationship. Therefore, the KPSS unit root test, introduced by Kwiatkowski et al. (1992), was employed to evaluate the stationary nature of the variables. However, the efficacy of traditional methods like KPSS diminishes in the presence of structural breaks. Consequently, the Zivot-Andrews (ZA) test, proposed by Zivot and Andrews in 2002, which accounts for a single break, is utilized in this study. The timing of the structural break is internally determined in the ZA unit root test, where each series is permitted one structural break.

## Results

### Dual Adjustment Approach

The current investigation uses the dual adjustment strategy, as proposed by Afolayan et al., (2020). This approach's principal reference example is the classic Engle-Granger (EG) cointegration technique. As a result, this study incorporates both the dual adjustment strategy and the EG cointegration method. An important feature of the dual adjustment approach is the offer of an alternative to cointegration analysis, which relaxes the implicit

assumption of single adjustment in such analyses. Following the recommendations of Azam et al., (2016)and Afolayan et al., (2020), the study uses the indirect technique and the Hodrick-Prescott (HP) filter to determine the trend and permanent components of the variables. Indeed, the HP filter is the preferred decomposition approach in current analysis for a variety of reasons, as previously stated, but this preference does not necessarily imply superiority over alternative methods. As a result, the dual adjustment strategy allows for the inclusion of additional popular filters in the current study, such as the Baxter-King filter (BK) recommended by Baxter and King, 1999), the Ravn and Uhlig (RU) filter, and the Christiano and Fitzgerald (CF) filter (as suggested by Christiano and Fitzgerald, 2003). According to Farooq et al., (2019), The dual adjustment strategy begins with dividing the variable into two different components. The HP technique is thought to be more effective for decomposition. Nonetheless, when using the HP approach, selecting the smoothing parameter is a vital step. In the HP method, the lambda value for data frequency is set to 100. However, when dealing with annual data, RU recommends a value of 6.25. As a result, this study employs two different lambda values, namely 100 and 6.25. The inquiry additionally uses BK and CF to pick the smoothing parameter. Furthermore, the investigation includes the essential parameters from the EG technique for the Co-HP trend analysis.

**Long-Run Estimators (FMOLS, DOLS and DOLS)**

Fully modified OLS (FMOLS) is considered one of the most appropriate options for predicting long-term elasticities due to its ability to account for autocorrelation and endogeneity difficulties within the dataset (Haines et al., 2009). This approach, introduced by Alleyne et al., (2013), uses a non-parametric technique and is very good at obtaining consistent findings with small sample numbers. The study's independent and dependent variables had a distinct relationship, which was shown using a statistical technique. To assess the dependability of the FMOLS results, the long-run estimators DOLS and CCR were used.

**Breitung and Candelon Causality**

DOLS, CCR, and FMOLS techniques are only focused on examining the relationship between independent and dependent variables. As a result, to determine the causal effect of $CO_2$ emissions, natural resources, GDP, and urbanization on health spending in Bangladesh, we employed the Breitung and Candelon (BC) Causality test. Alola et al. (2021) and Adebayo and Rjoub (2021) pointed out the key distinction between time-domain and frequency-domain approaches is that the former reveals the timing of a specific adjustment within a time series, whilst the latter determines the extent of a specific variance in the series. The BC approach exposes causation at several frequencies.

**Discussion**

**Pre-Estimation Outcomes:** Table 1 shows the statistical summary for the factors being investigated. The greatest average, observed in GDP (4361.5), ranging from 1723.5 to 7984.3. Concurrently, URB (47.707) ranges from 35.446 to 59.592, $CO_2$ (5.3817) ranges from 2.5775 to 7.0459, NRR (2.3677) ranges from 0.5718 to 5.9863, and HE (1.9947) ranges from 0.9493 to 3.0725. The skewness study shows that $CO_2$ and URB have negative skewness, but GDP, HE, and NRR have positive skewness. Furthermore, kurtosis values indicate that all variables ($CO_2$, HE, GDP, NRR, and URB) are leptokurtic. The study used the KPSS unit root test to determine the stationarity of HE, GDP, URB, NRR, and $CO_2$. Table 2 shows that HE, GDP, $CO_2$, NRR, and URB display stationarity at the level. However, in the presence of structural fractures, established approaches such as KPSS may lose their usefulness. As a result, the research used the Zivot Andrews (ZA) test, which accounts for a single break. Table 2 shows that all variables are integrated to order 1, with HE, GDP, $CO_2$, NRR, and URB experiencing breaks in 2010Q2, 2007Q2, 2011Q2, 2014Q2, and 2005Q2, respectively.

**Dual Adjustment Approach Outcomes:** The current study used the dual adjustment methodology. The first step is to determine the presence of Co-HP Trend. The hypothesis that there is no shared HP trend is universally rejected across all scenarios, using four different smoothing factors. Table 3 presents the Dual Adjustment Approach's findings in detail. In each case, there is evidence of a long-term relationship between health-care spending and economic growth, urbanization, natural resources, and $CO_2$ emissions. The Co-HP trend and Engle-Granger Critical Values both point to this conclusion. The smoothing parameters RU, HP, CF, and BK are used to analyze the Co-HP trend. Additionally, the results of Engle-Granger and Co-HP trend cointegration are similar. The EG/Co-HPw values are significant, which refutes the premise of no cointegration. As a result, there is a consistent HP trend across HP, RU, BK, and CF in all cases. The findings demonstrate that health spending is consistent with a shared component of economic growth, $CO_2$ emissions, natural resources, and urbanization (Co-HP trend). The λBK, λRU, λCF, and λHP investigations found a positive long-term correlation between economic growth, $CO_2$ emissions, and health spending. This shows that as economic growth, urbanization, and $CO_2$ levels rise, so will Bangladesh's health-care costs. Furthermore, it was discovered that natural resource rent has a detrimental impact on health spending in Bangladesh. This suggests that an increase in natural resource rents reduces the country's health-care cost. The short-term results of λHP and λRU show that $CO_2$ emissions have a favorable influence on health spending. Studies by λBK, λRU, λCF, and λHP showed a negative association between economic growth and health expenditure. The investigations by λHP and λRU also found a negative correlation between health spending and natural resources.

**Table 1.** Descriptive statistics.

| | $CO_2$ | GDP | HE | NRR | URB |
|---|---|---|---|---|---|
| Mean | 5.3817 | 4361.5 | 1.9947 | 2.3677 | 47.707 |
| Median | 5.692 | 4130.3 | 2.1345 | 1.9032 | 47.879 |
| Maximum | 7.0459 | 7984.3 | 3.0725 | 5.9863 | 59.592 |
| Minimum | 2.5775 | 1723.5 | 0.9493 | 0.5718 | 35.446 |
| Std. Dev | 1.6179 | 1929.3 | 0.7421 | 1.483752 | 7.202 |
| Skewness | −0.5203 | 0.2621 | 0.0226 | 0.718 | −0.0490 |
| Kurtosis | 1.7739 | 1.7708 | 1.3988 | 2.544 | 1.7821 |
| Jarque-Bera | 8.1893 | 5.6545 | 8.1244 | 7.1898 | 4.7274 |

**Table 2.** Unit root test

**TABLE 2 |** Unit root tests.

| | KPSS unit root test | | | | |
|---|---|---|---|---|---|
| | **HE** | **GDP** | **$CO_2$** | **NRR** | **URB** |
| t-statistic | 0.1702*** | 0.2756* | 0.2881* | 0.2563* | 0.3043* |
| | **Δ HE** | **Δ GDP** | **Δ $CO_2$** | **Δ NRR** | **Δ URB** |
| t-statistic | 0.1102 | 0.1958** | 0.1112 | 0.0726 | 0.1075 |
| | **ZA Unit Root Test** | | | | |
| | **HE** | **GDP** | **$CO_2$** | **NRR** | **URB** |
| t-statistic | −4.9820 | −3.8402 | −4.4688 | −4.3687 | −3.2018 |
| SB | 2010Q2 | 2009Q2 | 2010Q1 | 2007Q2 | 2016Q1 |
| | **Δ HE** | **Δ GDP** | **Δ CO2** | **Δ NRR** | **Δ URB** |
| t-statistic | −5.6527** | −5.5556** | −4.9683*** | −5.1842** | −44.346* |
| SB | 2010Q2 | 2007Q2 | 2011Q2 | 2014Q2 | 2005Q2 |

*1, 5 and 10% significance level are depicted by *, ** and ***. Δ represents the first difference. SB stands for structural break date.*

**Table 3.** EG and Co-HP trend tests.

**TABLE 3 |** EG and Co-HP trend tests.

| | Engle-Granger CI analysis | Co-HP trend analysis | | | |
|---|---|---|---|---|---|
| | | $\lambda_{HP}$ | $\lambda_{RU}$ | $\lambda_{BK}$ | $\lambda_{CF}$ |
| C | 2.446 (16.655)* | 4.223 (15.458)* | 3.628 (12.606)* | 22.907 (22.31)* | 19.704 (23.157)* |
| GDP | 1.285 (2.642)*** | 1.115 (11.207)* | 1.364 (4.119)** | 6.941 (5.978)* | 6.688 (7.0648)* |
| $CO_2$ | 1.193 (5.011)* | 1.174 (21.238)* | 1.030 (6.148)* | 0.890 (1.3847) | 0.542 (0.9532) |
| NRR | −0.204 (−5.369)* | −0.221 (−23.202)* | −0.181 (−6.503)* | −0.245 (−3.009)* | −0.205 (−2.8082)** |
| URB | 4.316 (2.602)*** | 3.795 (11.342)* | 4.182 (3.661)** | 21.767 (5.755)* | 0.001 (1.7387) |
| DUM | 0.031 (0.3472) | 1.181 (15.922)* | 0.505 (3.276)** | 0.018 (0.2155) | −20.236 (−5.854)* |
| EG/Co-HP[w] | −5.980 [0.007]* | −4.807 [0.066]*** | −5.103 [0.013]** | −6.075 [0.003]* | 5.353 [0.033]** |
| GDP | - | −3.895 (−5.646)* | −3.187 (−6.320)* | −2.045 (−1.7649)*** | −2.776 (−2.614)*** |
| $CO_2$ | - | 1.159 (4.324)* | 0.953 (4.123)* | 0.735 (1.029) | 0.933 (1.430) |
| NRR | - | −0.085 (−6.131)* | −0.082 (−10.757)* | −0.043 (−1.516) | −0.034 (−1.388) |
| URB | - | 6.254 (1.402) | 3.942 (4.960)* | 7.455 (2.119)** | 4.264 (2.512)** |
| DUM | - | −0.007 (−0.887) | −0.002 (−1.193) | −0.064 (−0.737) | −0.116 (−1.944)*** |
| Λ | - | 100 | 6.25 | - | - |

*HP, Hodrick-Prescott (Lambda = 100); RU, Rawn-Uhlig (Lambda = 6.25); BK, CF illustrates, Baxter-King and Christiano-Fitzgerald. 1, 5 and 10% significance level are illustrated by *, ** and *** respectively. p-value, and T-statistics are depicted by () and [] correspondingly.*

**Table 4.** Long run estimators (FMCLS, DOLS, CCR) outcomes.

**TABLE 4 |** Long-run run estimators (FMOLS, DOLS, CCR) outcomes.

| | FMOLS | | | DOLS | | | CCR | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Coefficient** | **t-Statistic** | **Prob** | **Coefficient** | **t-Statistic** | **Prob** | **Coefficient** | **t-Statistic** | **Prob** |
| GDP | 1.3161* | 3.0384 | 0.0034 | 1.3785* | 3.6223 | 0.0006 | 1.3315* | 2.6634 | 0.0096 |
| $CO_2$ | 0.9454* | 4.7195 | 0.0000 | 0.9411* | 4.5622 | 0.0000 | 0.9012* | 3.6762 | 0.0005 |
| NRR | −0.1355* | −4.1404 | 0.0001 | −0.1375* | −4.3055 | 0.0001 | −0.1418* | −3.5572 | 0.0007 |
| URB | 3.6676** | 2.5278 | 0.0139 | 3.8610* | 3.0139 | 0.0036 | 3.7252** | 2.2310 | 0.0289 |

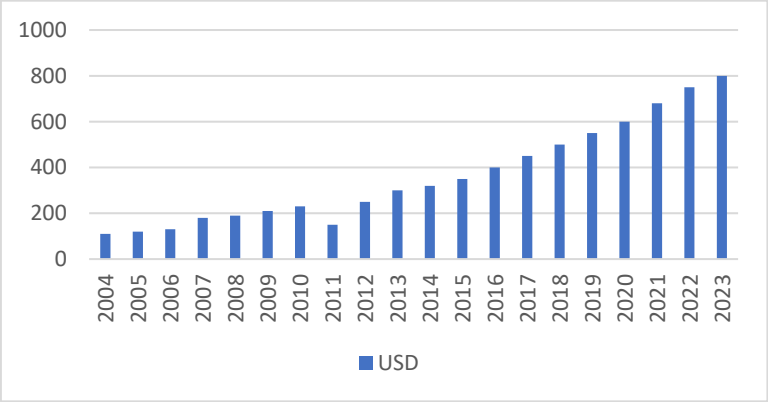


**Figure 1.** Per Capita Health Expenditure

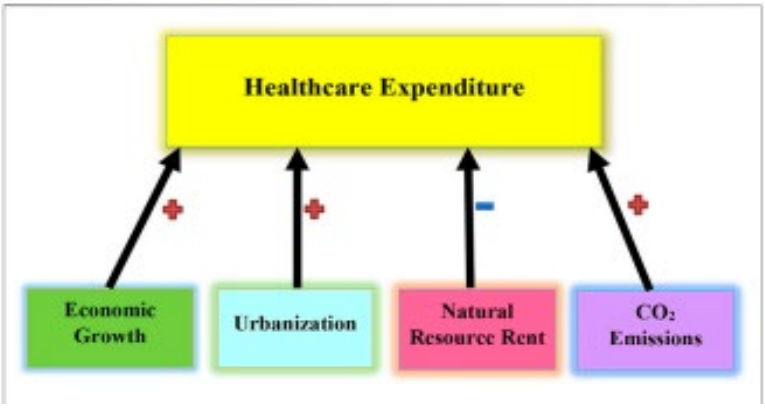


**Figure 2** Graphical Findings from FMOLS, DOLS and CCR

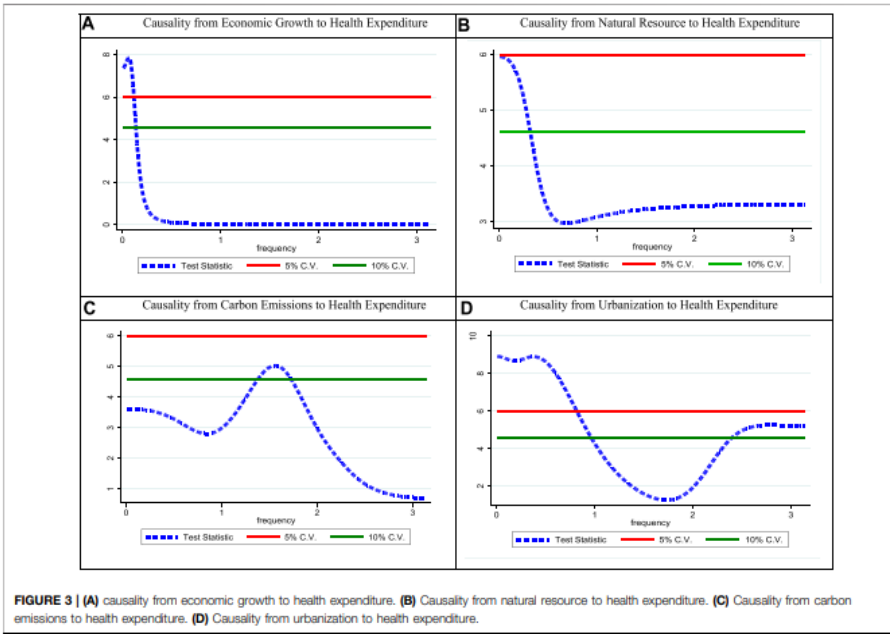


**FIGURE 3 | (A)** causality from economic growth to health expenditure. **(B)** Causality from natural resource to health expenditure. **(C)** Causality from carbon emissions to health expenditure. **(D)** Causality from urbanization to health expenditure.

**Long-Run Estimators (DOLS, CCR and FMOLS) Outcomes:** We also used Dynamic Ordinary Least Squares (DOLS), Canonical Cointegrating Regression (CCR), and Fully Modified Ordinary Least Squares (FMOLS) to capture the long-term relationship between health expenditure and its determinants in Bangladesh. Table 4 shows the results obtained from FMOLS, DOLS, and CCR. Our data show that economic growth and health expenditure are positively correlated. This shows that, assuming all other factors remain constant, a 1% rise in economic growth results in a 1.3161% increase in health expenditure (FMOLS), 1.3785% (DOLS), and 1.3315% (CCR). In addition, we discovered a positive relationship between health expenditure and $CO_2$ emissions in Bangladesh. This means that, all other things being equal, a 1% increase in $CO_2$ emissions causes a 0.9454% (FMOLS), 1.9411% (DOLS), and 0.9012% (CCR) increase in health spending. Previous studies conducted by Chaabouni et al. (2016), Chaabouni and Saidi (2017), and Shahzad et al. (2020) have observed similar findings, indicating a relationship between economic development, $CO_2$ emissions, and rising health-care spending. Economic growth is critical to national success because it provides a consistent mechanism for promoting both social and economic improvement. However, the pursuit of economic growth frequently leads to an increase in $CO_2$ emissions and, as a result, an increase in global health expenditure due to associated energy consumption and resource exploitation. This highlights the fact that the proportion of GDP allocated to health is increasing as a result of rising pollution and environmental-related illnesses caused by economic growth. Furthermore, the study identifies $CO_2$ as a main factor negatively impacting public health, underlining the necessity for policymakers to prioritize $CO_2$ reduction through the implementation of appropriate policies. Additionally, Chaabouni and Saidi (2017) have highlighted the importance of healthcare expenditures in driving a country's economic growth, implying that increased health spending can result in improved economies of scale, social protection, and effective resource management. Furthermore, studies show that natural resources have a detrimental impact on health costs. This shows that, holding all other variables equal, a 1% increase in natural resource rent reduces health spending by 4.1404% (FMOLS), 4.3055% (DOLS), and 0.1418% (CCR), respectively. The study's findings show that increasing the exploitation of natural resources leads to a decrease in health costs. This is crucial since the impact of natural resources on health expenditure has been largely disregarded in previous research. As a result, academics are likely to be motivated to dive deeper into the link between natural resources and health costs. A study conducted by Shahzad et al. (2020) also found a similar connection by establishing a negative link between natural resources and health expenditure. Finally, the impact of urbanization on health spending is negative, implying that, with all other factors held constant, a 1% increase in urbanization results in a 3.667% (FMOLS), 3.861% (DOLS), and 3.725% (CCR) increase in health expenditure. This finding is not surprising given Bangladesh's rapid urbanization in recent years. As a result, an increase in the urban population is predicted to raise the country's healthcare costs. Çetin and Bakırtaş's (2019) study on developing nations found similar results. Figure 2 shows a graphical depiction of the findings.

**Breitung and Candelon Causality Outcomes:** The current study used the approach created by Breitung and Candelon (BC) to determine the causal influence of $CO_2$ emissions, natural resources, economic growth, and urbanization on health expenditure in Bangladesh. The BC technique demonstrates causation at various temporal frequencies. Figures 3A–D show the findings of the BC causality test. In these graphics, the Test-statistic is represented by a broken-thick blue line, whereas the 5 and 10% significance levels are represented by red and green thick lines, respectively. Figure 3A illustrates spectral causation between economic growth and health expenditure. The long-term rejection of the null hypothesis of "no causality" at the 5% and 10% significance levels implies that economic growth can predict health expenditure in Bangladesh. Similarly, figures 3A-3D show causality from natural resources to health expenditure, with the results rejecting the null hypothesis of "no causality" at the 5% and 10% levels of significance in the long run. Furthermore, a causal link between $CO_2$ emissions and health spending is detected in the medium term at a 10% significance level. Finally, evidence of a causal relationship between urbanization and health expenditure exists at the 5% and 10% significance levels, respectively. Finally, natural resources, economic growth, urbanization, and $CO_2$ emissions all have predictive power for health expenditure. As a result, all policy initiatives aimed at natural resources, economic growth, urbanization, and $CO_2$ emissions will have an impact on health spending.

## Conclusion

Emerging economies are increasingly facing healthcare issues as their urban populations grow rapidly. Infrastructure deficiencies, problems in social change, rapid urbanization, and challenges in providing healthcare services, among other factors, have serious economic consequences for emerging countries. Although academics and scholars have studied the determinants of healthcare spending across various samples since the 1970s, there have been few studies that focus on the potential effects of urbanization and natural resources on health expenses. Therefore, our analysis aims to evaluate the influence of natural resources, economic growth, urbanization, and $CO_2$ emissions on health expenditure. In addition, the study employs a quarterly dataset covering the period from 2000 to 2018 in the context of Bangladesh. Both the KPSS and ZA unit root tests were applied to ascertain the stationary characteristics of the variables, revealing that they are I (1) and I (0)

respectively. Additionally, a novel dual adjustment methodology was used to evaluate the cointegration connection between the independent and dependent variables. The dual adjustment approach stands out for its capacity to improve cointegration analysis by eliminating the implicit assumption of single adjustment. The results of this approach proved the presence of cointegration between the variables. Furthermore, the study used the FMOLS, DOLS, and CCR methodologies to capture the long-term link, demonstrating that economic growth, $CO_2$ emissions, and urbanization have a positive impact on health spending, whereas natural resources have a negative effect. Finally, the BC test results show the behavior of all variables (natural resources, economic growth, urbanization, and $CO_2$ emissions) at various frequencies.

## Author contributions

M.F.I. is the principal author, responsible for setting objectives, data analysis, and the final revision of the paper. S.D. contributed by writing the abstract, methods, and materials sections. H.D. wrote the introduction. F.H. conducted the literature review. S.S. wrote the results section. R.D. collected data from the selected sources. B.M. handled the discussion. M.H. contributed to the significance, keywords, and conclusion. All authors reviewed and approved the final manuscript.

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## Competing financial interests

The authors have no conflict of interest.

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