Med Res Rep 2025;8(3):167-181
https://doi.org/10.55517/mrr.1793949

ORIGINAL ARTICLE

The Impact of Carbon Dioxide Emissions on Health Expenditures in Developing Countries

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ABSTRACT

Aim: This study aims to measure the long-run effects of changes in carbon dioxide (CO_2) emissions on total (public and private) health expenditures in twenty developing countries over the period 2000–2021. Situated at the intersection of environmental, health, and fiscal policy often sidelined in the literature it seeks to make emission-sensitive budget dynamics visible through a quantitative, cross-country–heterogeneous framework and to provide evidence-based input for policy design. **Method:** The dataset comprises health expenditures, CO_2 emissions, Gross Domestic Product (GDP), urbanization rate, and labor force participation. Cross-sectional dependence is assessed using the LM test; stationarity is examined with the second-generation CIPS unit root tests. Long-run relationships are verified via the Westerlund cointegration test, and slope heterogeneity is evaluated with the Pesaran–Yamagata test. Long-run coefficients and country-specific elasticities are estimated using the Pedroni Dynamic Ordinary Least Squares Mean Group (DOLSMG) estimator, which accounts for endogeneity and heterogeneity. Robustness checks include alternative weightings and sub-sample analyses. **Results:** Panel-average estimates indicate that a 1% increase in CO_2 emissions raises health expenditures by approximately 1.18% in the long run. Control variables behave as expected: a 1% rise in GDP increases health expenditures by about 1.39%; urbanization by 4.75%; and labor force participation by 0.38%. Marked cross-country heterogeneity emerges: Saudi Arabia, Russia, India, Türkiye, South Africa, and Vietnam display strong positive CO_2 expenditure elasticities, whereas Egypt, Pakistan, Kazakhstan, and Argentina exhibit negative coefficients. These differences are consistent with reporting practices, fiscal constraints, the breadth of health system coverage, and composition effects linked to the morbidity profile of emissions. An elasticity greater than one implies a disproportionate budgetary burden from rising emissions. **Conclusion:** CO_2 emissions significantly and strongly increase health expenditures in the long run. These finding positions carbon mitigation not only as an environmental objective but also as a medium-term cost-containment instrument for health policy. Policy implications include: (i) allocating carbon pricing revenues to climate-resilient health infrastructure; (ii) designing coordinated packages that pair emission control with public health investments tailored to country-specific vulnerabilities; and (iii) mitigating pollution intensity associated with urbanization through transport/housing planning and strengthening primary care. Overall, the results underscore the need for integrated, country-specific coordination between environmental policy and health budgeting.

Keywords: Carbon dioxide emissions, Developing countries, DOLSMG, Health expenditures

ÖZET

Amaç: Bu çalışma, 2000 ile 2021 yılları arasında yirmi gelişmekte olan ülkede karbondioksit (CO_2) emisyonlarındaki değişimlerin kamu ve özel toplam sağlık harcamaları üzerindeki uzun dönemli etkisini ölçmeyi amaçlamaktadır. Literatürde çoğu kez geri planda kalan çevre, sağlık ve maliye alanlarının kesişiminde, emisyonlara duyarlı bütçe dinamiklerini ülkeler arası farklılıkları dikkate alan nicel bir yaklaşımla görünür kılmak ve politika tasarımına kanıta dayalı katkı sunmak hedeflenmiştir. **Yöntem:** Veri seti, sağlık harcamaları, CO_2 emisyonları, kişi başına gayri safi yurtiçi hasıla (GSYH), kentleşme oranı ve işgücüne katılım değişkenlerinden oluşur. Panelde yatay kesit bağımlılığı LM testiyle sınanmış; durağanlık ikinci nesil CIPS birim kök testleriyle incelenmiştir. Uzun dönem ilişki Westerlund eşbütünleşme testiyle teyit edilmiş; eğim heterojenliği Pesaran–Yamagata testiyle değerlendirilmiştir. Uzun dönem katsayılar ve ülke-bazlı esneklikler, içsellik ve heterojenliği gözeten Pedroni DOLSMG tahmincisiyle elde edilmiştir. Sağlamlık için alternatif ağırlıklandırmalar ve alt-örnek kontrolleri uygulanmıştır.

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Bulgular: Panel-ortalama sonuçlar, CO_2 emisyonlarındaki %1'lik artışın sağlık harcamalarını uzun dönemde yaklaşık %1,18 artırdığını göstermektedir. Kontrol değişkenleri beklenen yöndedir: GSYH'da %1'lik artış harcamaları ~%1,39; kentleşme %4,75; işgücüne katılım %0,38 ölçüsünde yükseltmektedir. Ülke düzeyinde belirgin heterojenlik saptanmıştır: Suudi Arabistan, Rusya, Hindistan, Türkiye, Güney Afrika ve Vietnam'da CO_2–harcama esnekliği pozitif ve güçlü; Mısır, Pakistan, Kazakistan ve Arjantin'de ise negatif katsayılar gözlenmiştir. Bu farklılaşma, raporlama farkları, mali kısıtlar, sağlık sistemi kapsayıcılığı ve emisyonların morbidite profiliyle ilişkili kompozisyon etkileriyle tutarlıdır. Esneklik değerinin birden büyük olması, artan emisyonların sağlık bütçesi üzerinde orantısız yük doğurduğunu ima etmektedir. **Sonuç:** CO_2 emisyonları sağlık harcamalarını uzun dönemde anlamlı ve güçlü biçimde artırmaktadır. Bu bulgu, karbon azaltımını yalnız çevresel bir hedef değil, aynı zamanda orta vadede maliyet düşürücü bir sağlık politikası aracı olarak konumlandırır. Politika düzeyinde (i) karbon fiyatlaması gelirlerinin iklim dirençli sağlık altyapısına tahsisi, (ii) ülke-özel kırılganlıklara göre eş zamanlı emisyon kontrolü–halk sağlığı yatırımı paketleri, (iii) kentleşmenin kirletici yoğunluğunu azaltacak ulaşım/konut planlaması ve birinci basamak güçlendirmesi önerilir. Bulgular, çevre politikaları ile sağlık bütçelemesi arasında bütüncül, ülkeye özgü bir eşgüdüm gerektirdiğini açıkça göstermektedir.

Anahtar Kelimeler: Karbondioksit emisyonları, Gelişmekte olan ülkeler, DOLSMG, Sağlık harcamaları

Cite this article as: Bas B. The Impact of Carbon Dioxide Emissions on Health Expenditures in Developing Countries. Medical Research Reports 2025;8(3):167-181.

INTRODUCTION

Rising levels of CO2 emissions an important driver of anthropogenic climate change have far-reaching impacts on the global health system, particularly in developing countries. Although these countries contribute minimally to global greenhouse gas emissions compared with advanced economies, they are disproportionately vulnerable to the health and economic consequences of climate change (1). For example, in Sub-Saharan Africa—where health systems are already under strain—the additional burden of climate-sensitive diseases can stretch scarce resources and drive increases in health expenditures (2). Similarly, in South Asia, rising temperatures and extreme weather events such as floods and cyclones are associated with higher incidence of waterborne diseases and undernutrition, further inflating the costs of health care provision (3).

The economic burden of health impacts attributable to CO_2 emissions can be substantial. Developing countries often characterized by limited health infrastructure, inadequate financing, and relative poverty face significant challenges in managing the rising costs associated with climate-related health outcomes (4). Increased health expenditures driven by higher morbidity and mortality displace resources from other critical development priorities, thereby perpetuating cycles of poverty and inequality (5). The economic consequences of health risks are not confined to direct medical spending: indirect costs such as productivity losses due to illness and premature mortality can also generate significant macroeconomic repercussions. Diminished labor productivity and heightened demand for health services place additional strain on national economies, undermining efforts toward sustainable development. A study by Markandya et al. (6) indicates that, in developing countries, the economic costs of climate-related health impacts may amount to billions of dollars annually, diverting resources from other essential development priorities such as education and infrastructure.

Despite growing recognition of the linkages between climate change and health, research that specifically examines the effect of CO_2 emissions on health expenditures in developing countries remains limited. This article seeks to contribute to the literature by investigating the mechanisms through which CO_2 emissions influence health-care costs in this set of countries. By highlighting the distinctive vulnerabilities of developing economies and quantifying the economic burden of climate-sensitive health risks, the study aims to inform policymakers and underscore the urgent need for sustainable development strategies (7).

The relationship between CO_2 emissions and health expenditures is a critical area of inquiry in environmental economics and public health. This linkage rests on the interaction among environmental degradation, population health, and economic systems. The Environmental Kuznets Curve (EKC) hypothesis posits an inverted-U relationship between environmental degradation and economic development. At low-income levels, economic growth driven by industrialization and energy-intensive activities tends to increase pollution. However, once income surpasses a certain threshold, societies invest in cleaner technologies and environmental regulations, leading to reductions in pollution levels (8).

Within the health production function framework derived from Grossman's (9) health capital model, health outcomes are shaped by a combination of individual behaviors, health services, and environmental conditions. As a source of environmental pollution, CO_2 emissions act as a negative input in the health production function. Consequently, in the early stages of economic development, rising CO_2 emissions can exacerbate health problems and increase health expenditures. As economies mature and emissions decline, improvements in environmental quality alongside strengthened health infrastructure may stabilize or even reduce health expenditures (10).

CO_2 emissions typically encompass co-pollutants (e.g., particulate matter, nitrogen oxides) that directly harm the respiratory and cardiovascular systems and increase the prevalence of conditions such as asthma and chronic obstructive pulmonary disease (COPD) (11). By driving climate change, CO_2 emissions can also alter the geographic distribution of vector-borne diseases such as malaria and dengue fever, thereby imposing additional pressures on health systems (12).

Within the health capital model, three principal mechanisms are salient. The first is the direct morbidity channel. Morbidity refers to the incidence of a specific disease or the presence of a defined medical condition during a given period. CO_2-intensive production processes commonly release co-pollutants such as $PM_{2.5}$ (Particulate matter with an aerodynamic diameter of 10 micrometers or less (PM_{10}) consists of inhalable particles that can penetrate the lungs and lead to adverse health effects.), NO_x (NO_x refers to nitrogen oxides—principally nitric oxide (NO) and nitrogen dioxide (NO_2)), and SO_2 (Sulfur dioxide). This mixture triggers oxidative stress in the airways, increasing the risk of asthma exacerbations, acute respiratory infections, and arteriosclerosis (13). According to a study published in 2024, exposure to such pollutants raises cardiovascular hospital admissions by 8–10% and exerts an additional budgetary pressure equivalent to roughly 5% of total health expenditures in low- and middle-income countries (14). Similarly, in a panel analysis covering 101 emerging economies, Yadav et al. (15) find that a 1% increase in CO_2 emissions is associated with a 0.21% long-run rise in per capita health expenditures, with particularly pronounced cost increases in respiratory pharmaceuticals and emergency care categories.

Another mechanism is the indirect climate channel. CO_2-driven global warming imposes a second layer of strain on health systems through the lengthening of heat waves, the poleward spread of vector populations into formerly non-tropical regions, and the rising frequency of hydrometeorological disasters (floods, droughts). According to the Intergovernmental Panel on Climate Change (IPCC), the period 2000–2019 saw a 53% increase in climate-related mortality, with the largest rises observed in sub-Saharan Africa and South Asia (16). The Lancet Countdown 2024 report estimates that in 2023, additional health expenditures attributable to climate shocks totalled USD 11.5 billion, noting that 84% of this burden was borne by developing-country budgets (17). A Lancet study focusing on small island states shows that rising sea surface temperatures have increased cases of ciguatera poisoning and diarrheal disease, severely overstretching already fragile health infrastructure (18).

The final mechanism is the fiscal sustainability channel. Unexpected surges in health expenditures compress the already limited fiscal space of developing countries, crowding out long-term, growth-oriented investments in areas such as education, safe water and sanitation, and transportation. The IMF's 2023 surveillance note indicates that in low- and middle-income economies, each 0.1-percentage-point increase in public health outlays above 1% of GDP is associated with a 0.06-percentage-point decline in the public investment rate (19). Examining 124 low- and middle-income countries over 2000–2018, Behera, D.K. et al. (20) find that health expenditures linked to rising CO_2 significantly suppress infrastructure appropriations, with the effect weakening as per-capita GDP rises. At the household level, high medical outlays especially among poorer groups induce trade-offs that reduce essential consumption such as food and housing, thereby deepening the cycle of poverty (21).

The theoretical framework linking urbanization to health expenditures rests on four interrelated channels. First is the income and insurance effect: urbanization formalizes labor markets, expanding the tax base and the coverage of social insurance. Rising per capita income and mandatory insurance premiums tend to increase total health expenditures, particularly their public component (8,22). Second is the epidemiological transition: rural-to-urban migration may reduce exposure to infectious disease, yet sedentary lifestyles and dietary change elevate the prevalence of chronic conditions such as obesity, diabetes, and hypertension. The long-term treatment needs associated with chronic morbidity exert persistent upward pressure on health expenditures (23-25). Third, environmental externalities emerge as an unintended by-product of urban density. Air pollution, noise, and urban "heat island" effects raise the costs of respiratory and cardiovascular disease. The 2014 global respiratory burden report indicates that these cost increases are especially pronounced in megacities with high $PM_{2,5}$ concentrations (26). Finally, the infrastructure and economies-of-scale channel is two-sided: dense populations can raise capacity utilization of hospital beds and primary-care clinics, lowering unit costs; however, if the pace of urbanization outstrips investment in health infrastructure, congestion effects can drive expenditures back up. Evidence from China where urbanization significantly increases health expenditures in the Eastern and Central regions but has a more limited effect in the West due to infrastructure constraints corroborates this dual mechanism (27). Household data from Vietnam, showing declines in hospital spending alongside increases in over-the-counter medicine outlays, similarly reflects a mismatch between capacity and demand (28).

Literature

The body of research examining the relationship between health expenditures and the environment remains limited. A subset of these studies investigates the linkage between environmentally induced diseases and health expenditures. For example, Hales (29) shows that dengue outbreaks in Southeast Asia are associated with higher temperatures and humidity, which in turn lead to increases in hospital admissions and health expenditures. Patz (30), in related work, finds that rising temperatures and changing precipitation patterns have increased malaria incidence in sub-Saharan Africa. The study projects that climate change could generate an additional 200 million malaria cases annually by 2050, with substantial implications for health-care costs.

Another strand of the literature analyses the association between CO_2 emissions and health expenditures. Narayan (31), using panel data for 50 developing countries, finds that a 1% increase in CO_2 emissions is associated with a 0.7% rise in public health expenditures. The study underscores that poorer countries face a relatively heavier fiscal burden as a share of gross domestic product. Chaabouni (32) investigates the causal relationships among CO_2 emissions, health expenditures, and economic growth for a panel of 51 countries over 1995–2013, concluding that there is a unidirectional relationship running from CO_2 emissions to health expenditures. Similarly, Usman (33) examines 13 developing countries over 1994–2017 controlling for GDP, foreign direct investment, and population and finds that CO_2 emissions increase health-care spending.

Environmental pollution arises from multiple sources and leads to diverse health problems; accordingly, the relationship between health expenditures and environmental pollution has been analysed in the literature using various environmental indicators. Zheng (34) analyses data from 20 developing countries and finds that a 10% increase in the concentration of fine particulate matter ($PM_{2.5}$) is associated with a 3.5% rise in health expenditures for respiratory diseases. Employing econometric models to control for socioeconomic factors, the study further shows that urban areas are disproportionately affected. Raeissi (35), using data for Iran over 1972–2014, investigates the long-run impact of air pollution on health expenditures and reports that a 1% increase in the CO2 index is associated with increases of 3.32% and 1.16% in public and private health expenditures, respectively. Jerrett (36) examines the association between health expenditures and environmental variables across 49 counties in Ontario, Canada, using ecological data; after controlling for other determinants of health expenditures, the results indicate higher health expenditures in counties with greater pollution outputs, whereas counties that invest in improving environmental quality exhibit lower health-care spending. The World Bank (2016) estimates that productivity losses attributable to air pollution impose annual costs exceeding USD 500 billion in India and China. Anwar (37), analysing 33 developing countries over the period 2000–2017, finds that both air pollution and rising temperatures increase health expenditures.

A subset of the literature examines the relationship between environmental quality and health expenditures. Using data from 1995–2012, Yahaya (38) analyses 125 developing countries to assess the impact of environmental quality on per capita health expenditures. The study identifies a long-run cointegrating relationship between per capita health expenditures and all explanatory variables. Empirically, CO_2 emissions are statistically significant in explaining per capita health expenditures: a 1% increase in CO_2 emissions is associated with an 11% rise in per capita health expenditures. Alimi (39), employing data for 15 ECOWAS countries over 1995–2014, investigates the causal link between environmental quality and health expenditures. The findings indicate that CO_2 emissions exert positive and statistically significant effects on both public and private health expenditures.

MATERIAL AND METHODS

This study investigates the impact of CO_2 emissions on health expenditures. To this end, panel data were constructed for the period 2000–2021 using the 20 developing countries (China, India, Russia, Iran, Indonesia, Saudi Arabia, Brazil, Turkey, South Africa, Mexico, Poland, Vietnam, Thailand, Egypt, Malaysia, Pakistan, Kazakhstan, Argentina, Ukraine, Algeria) with the highest CO_2 emissions. The econometric model is specified as follows:

$$HE_{it} = \beta_0 + \beta_1 CO2_{it} + \beta_2 GSYH_{it} + \beta_3 KNT_{it} + \beta_4 \dot{I}G_{it} + \varepsilon_{it}$$

In the model, HE denotes health expenditures (USD) and serves as the dependent variable. CO2 represents carbon dioxide emissions (metric tons) and is the key independent variable. The control variables are GDP (gross domestic product in USD), URB (urbanization rate), and LFP (labor force participation rate). The variables HE, CO_2, and GDP enter the model in natural logarithms. Data on health expenditures are obtained from the World Health Organization (WHO), while the remaining variables are sourced from the World Bank. The analysis was conducted using Stata 15.

This study employs panel data methods. The panel data method is an effective tool for analysing data that includes multiple cross-sectional observations across multiple time periods. By combining cross-sectional and time-series dimensions, panel techniques enable researchers to control for unobserved heterogeneity and to better characterize dynamic relationships (40).

To determine the appropriate panel-data estimators, it is first necessary to examine the presence of cross-sectional dependence. This diagnostic is crucial for selecting suitable panel unit root tests.

Cross-sectional dependence is assessed using the Breusch–Pagan LM test. The test equation is specified as follows:

$$LM = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T . \hat{p}_{ij}^2$$

If the series under study exhibit a temporal dimension, it is necessary to assess stationarity. In this study, we employ a second-generation unit root test that accounts for cross-sectional dependence—the Cross-Sectionally Augmented Im, Pesaran, and Shin CIPS test. The test equation is presented below:

$$CIPS = \frac{1}{N} \sum_{i=1}^{N} CADF_i$$

To test the homogeneity of slope parameters, we employ the Δ test proposed by Pesaran and Yamagata (41). The Δ test statistic is given as follows:

$$\Delta = \sqrt{N \left(\frac{N^{-1}\hat{S} - k}{\sqrt{2k}} \right)}$$

It is important to determine whether a long-run equilibrium relationship exists among the variables. To this end, we employ a second-generation cointegration test, Westerlund's (42) cointegration test. The hypothesis testing framework is as follows: H_0: no cointegration; H_1: cointegration.

If the presence of long-run cointegration has been established, the next step is to estimate the long-run coefficients. When the panel is heterogeneous, it is

Pedroni's (43) DOLSMG estimator. By augmenting the DOLSMG specification with

leads and lags of the regressors X, feedback effects and endogeneity are mitigated.

Accordingly, a DOLS model is first specified for each cross-sectional unit as follows:

$$y_{it} = a_i + \beta_i x_i + \sum_{j=-q}^{q} \gamma_{ij} \Delta x_{i,t+j} + \epsilon_{it}$$

Here y_{it} is the dependent variable; x_iis the independent variable; β_i denotes the long-run coefficient; $\gamma_{ij}\Delta x_{i,t+j}$ captures the heterogeneous correction introduced by including leads and lags; and ϵ_{it} is the error term.

Subsequently, taking the cross-sectional mean yields the following aggregate specification:

$$\hat{\beta}_{MG} = \frac{1}{N}\sum_{i=1}^{N}\hat{\beta}_i$$

RESULTS

The results of the LM test for detecting cross-sectional dependence are presented in Table 1.

The results indicate the presence of cross-sectional dependence among the variables. Consequently, the analysis must employ second-generation unit root tests that account for such dependence. The unit root test results are reported in Table 2.

Table 1: Breusch-Pagan Lagrange MultiplierTest (LM) for Cross-sectional Dependence

Test	Statistic	p-value
Breusch-Pagan LM	183.4	$p<0.001$

Indicates significance at the $p<0.001$

Table 2: Cross-Sectionally Augmented Im, Pesaran, and Shin (CIPS) Unit Root Test Results

Levels						
Variables	**Constant**	**Critical Value (%5)**	**Critical Value (%1)**	**Trend**	**Critical Value (%5)**	**Critical Value (%1)**
HE	-2.108	-2.2	-2.38	-2.406	-2.72	-2.88
CO_2	-1.899	-2.2	2.38	-2.340	-2.72	-2.88
GSYH	-1.930	-2.2	2.38	1.808	-2.72	-2.88
KNT	-1.298	-2.2	2.38	-1.552	-2.72	-2.88
IG	-1.278	-2.2	2.38	-1.699	-2.72	-2.88

First difference						
Variables	**Constant**	**Critical Value (%5)**	**Critical Value (%1)**	**Trend**	**Critical Value (%5)**	**Critical Value (%1)**
HE	-3.934	-2.2	-2.38	-3.76	-2.72	-2.88
CO_2	-3.747	-2.2	-2.38	3.750	-2.72	-2.88
GSYH	-2.964	-2.2	-2.38	-2.99	-2.72	-2.88
KNT	-3.117	-2.2	-2.38	-3.01	-2.72	-2.88
IG	-3.162	-2.2	-2.38	-3.47	-2.72	-2.88

HE:Health Expenditures, CO_2: Carbon Dioxide Emissions, GSHY: Gross Domestic Product, KNT: Urbanization, IG: Labor Force Participation

The unit root tests indicate that the series are non-stationary in levels but become stationary after first differencing.

The homogeneity of the slope parameters is assessed using the Δ test of Pesaran and Yamagata. The results are presented in Table 3.

Based on the results, the null hypothesis H_0 of homogeneous slope parameters is rejected. Accordingly, cointegration tests and long-run coefficient estimators that accommodate slope heterogeneity must be employed.

The existence of a long-run relationship is examined using the Westerlund cointegration test. The results are reported in Table 4.

The analysis results rejected the null hypothesis H_0 of "no cointegration" (Gt, Ga, Pt, Pa $p<0.001$), indicating that the series are cointegrated in the long run. The DOLSMG estimator will be used to estimate the long-run coefficients. The long-run estimation results are presented in Table 5.

Table 3: Homogeneity Test Results (Pesaran and Yamagata Δ Test)

	Delta	**p-value**
	15.344	p<0.001
Adjusted Δ Testi	17.993	p<0.001

Indicates significance at the p<0.001

Table 4: Westerlund Panel Cointegration Test Results

	Test Statistic		p-value
Variance ratio	-1.7208		$p<0.001$
Statistic	**Value**	**Z-value**	**P-value**
Gt	-10.514	-46.278	$p<0.001$
Ga	-4.956	-7.785	$p<0.001$
Pt	-7.546	-14.785	$p<0.001$
Pa	-1.754	-6.723	$p<0.001$

"Gt" and "Ga" denote group statistics, whereas "Pt" and "Pa" denote panel statistics. Indicates significance at the $p<0.001$

Table 5: DOLSMG Long-Run Estimation Results

Variables	Beta	t-stat.
CO_2	1.18	13.83**
GSYH	1.389	21.59**
KNT	4.75	16.11**
IG	.384	15.26**

DOLS				DOLS			
Code	**Country**	**Beta**	**t-stat.**	**Code**	**Country**	**Beta**	**t-stat.**
1	China	-.2438	-1.935	**11**	Poland	1.444	14.13**
2	India	4.036	7.339**	**12**	Vietnam	3.346	28.22**
3	Russia	4.959	37.27**	**13**	Thailand	.59	5.071**
4	Iran	5.31	16.72**	**14**	Egypt	-2.593	-6.274**
5	Indonesia	2.313	35.19**	**15**	Malaysia	1.184	1.723
6	Saudi Arabia	8.863	19.76**	**16**	Pakistan	-2.171	-5.045**
7	Brazil	1.463	9.95**	**17**	Kazakhstan	-6.325	-48.27**
8	Türkiye	3.612	49.45**	**18**	Argentina	-1.455	-3**
9	South Africa	4.986	127.8**	**19**	Ukraine	.4324	9.763**
10	Mexico	2.133	2.489*	**20**	Algeria	1.698	17.12**

The t-table critical values are 1.96 for $\alpha = 0.05$ and 2.58 for $\alpha = 0.01$. The symbols ** and * denote significance at the 1% and 5% levels, respectively. HE:Health Expenditures, CO_2: Carbon Dioxide Emissions, GSHY: Gross Domestic Product, KNT: Urbanization, IG: Labor Force Participation

The DOLSMG estimates reported in Table 5 delineate the long-run relationship between health expenditures and CO_2 emissions for the twenty developing countries with the highest emissions over 2000–2021. Accounting for the heterogeneous panel structure and cross-sectional dependence, the chosen DOLSMG method yields a "panel-average" long-run relationship by taking the simple mean of coefficients estimated separately for each country. This approach allows both the overall pattern and country-specific results to be viewed within a single table.

According to the aggregate panel coefficients, a 1% increase in CO_2 emissions raises health expenditures by 1.18% in the long run. In the same table, the coefficient on GDP is 1.38, indicating that economic growth increases health expenditures even more strongly than CO_2 does—reflecting the joint effects of industrialization and rising incomes in expanding both budgetary capacity and disease burden. The urbanization variable stands out with a more than fourfold association ($\beta = 4.75$), suggesting that rapid metropolitanization simultaneously intensifies pollutant concentrations, exposure via population density, and demand for health services. Although more modest in magnitude, the labor-force-participation coefficient ($\beta = 0.384$) is statistically robust: as a larger share of the population enters production, employer-based insurance and welfare-demand channels expand overall health expenditures.

Examining the country-specific coefficients reveals substantial heterogeneity. In energy-intensive or fossil-fuel-dependent economies such as Saudi Arabia ($\beta = 8.863$; $t = 19.76$), Russia ($\beta = 4.959$; $t = 37.27$), and India($\beta = 4.036$; $t = 7.339$), the linkage between CO_2 emissions and health expenditures is sharply positive. In these countries, both high emissions volumes and rising pollutant concentrations in expanding urban centers amplify costs associated with respiratory diseases and heat stress. Similarly, in Turkey, South Africa, and Vietnam, the coefficients fall in the 3–5 range and are highly statistically significant. This pattern suggests that, amid rapid growth and urbanization, emissions-control measures have lagged.

By contrast, the estimates for China ($\beta = -0.244$; $t = -1.935$) and Malaysia ($\beta = 1.184$; $t = 1.723$) are not statistically significant at the 5% level; because health expenditures amounting to hundreds of billions of dollars annually are financed from the central budget via public subsidies, the emission effect may be relatively obscured within the fiscal accounts. Egypt ($\beta = -2.593$; $t = -6.274$), Pakistan ($\beta = -2.171$; $t = -5.045$), Kazakhstan ($\beta = -6.325$; $t = -48.27$), and Argentina ($\beta = -1.455$; $t = -3.000$), by contrast, exhibit statistically significant negative coefficients.

DISCUSSION

The findings of this study indicate that increases in CO_2 emissions exert a long-run and economically meaningful pressure on health expenditures in developing countries: the panel-average elasticity is approximately 1.18, implying that a 1% rise in emissions

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raises health spending by more than 1%. This magnitude suggests a disproportionate budgetary burden attributable to emissions and supports viewing carbon abatement not only as an environmental objective but also as a medium-term cost-containment instrument. In the same specification, the coefficients for GDP (≈ 1.39) and urbanization (4.75) are strong and of the expected sign, consistent with the interpretation that growth–metropolization dynamics push expenditures upward through both demand (expanded access and coverage) and supply (infrastructure and inclusiveness) channels. The labor force participation coefficient (0.384), while smaller yet statistically significant, points to the fiscal effects of formalization and the expansion of the insurance premium base.

Our results align with the empirical literature reporting a positive association between environmental degradation and health costs (30,33,38); however, the elasticity estimate exceeding unity provides stronger evidence of this relationship's fiscal severity. The study also deepens the emphasis on heterogeneity: in energy-intensive and rapidly urbanizing economies such as Saudi Arabia, Russia, India, Turkey, South Africa, and Vietnam, the large positive coefficients are consistent with a mechanism in which direct morbidity channels ($PM_{2,5}$/NO_X co-pollutants; respiratory–cardiovascular burdens) and indirect climate channels (heatwaves, floods/cyclones, vector-borne diseases) operate jointly (34). By contrast, the negative coefficients observed for Egypt, Pakistan, Kazakhstan, and Argentina point to two alternative explanations: (i) suppressed expenditure elasticity due to fiscal constraints/output gaps (budget retrenchment, external debt constraints, mandatory austerity programs); and (ii) differences in reporting and coverage (shifts of spending to off-budget channels, under-recording). These opposing signs make clear that one-size-fits-all policy prescriptions are inadequate.

The pattern of country-specific coefficients is consistent with three channels:

Direct morbidity: Co-pollutants that rise concurrently with increased emissions amplify acute and chronic respiratory and cardiovascular burdens, inflating emergency visits as well as pharmaceutical and treatment expenditures.

Indirect climate channel: Heat stress, flooding, and vector-borne diseases persistently elevate healthcare demand (29,30).

Fiscal sustainability: Shock-like health outlays, within constrained fiscal space, crowd out preventive investments and other development expenditures; in turn, this generates new waves of costs over the medium term. The magnitude of the panel-average estimates and the sizeable urbanization coefficient indicate that the combination of intense metropolization and inadequate emissions control multiplies fiscal burdens.

CONCLUSION

The findings generate policy implications for developing countries along two dimensions. First, an elasticity of the CO_2–health expenditure relationship greater than one indicates that reducing emissions is not merely an environmental policy but also a medium-term budget-saving strategy. Earmarking carbon tax revenues for infrastructure investments that render health systems climate-resilient could create a “double dividend.” Second, the opposing signs of country-specific coefficients imply that a one-size-fits-all policy prescription is inadequate. In countries with positive and relatively large coefficients, emissions control and public health should be prioritized concurrently, whereas in countries with negative coefficients the core problem is the chronic financing gap in health expenditures. In these cases, priority should be given to expanding health budgets in a sustainable and transparent manner alongside emissions mitigation. In sum, limiting CO_2 emissions is not solely an environmental objective; it is also a critical requirement for the fiscal sustainability of health systems.

Designing environmental and health policies within an integrated—rather than siloed—framework is an urgent necessity. Clean-energy investments—particularly solar, wind, and hydropower—can reduce CO_2 emissions and thereby curb the disease burden attributable to air pollution; over the long run, this transition yields substantial gains in both economic efficiency and public health. To support this objective, stricter industrial emissions standards, the diffusion of pollution-control technologies, and the adoption of sustainable urban-planning principles (accessible public transport, green spaces, compact settlement patterns) should be implemented. Concurrently, it is essential to increase resources allocated to health services; expand access in both urban and rural areas; and strengthen early-warning, surveillance, and response capacities for climate-sensitive diseases. Public education on the health risks associated with air pollution, reductions in personal carbon footprints, and the uptake of cleaner household energy sources constitute complementary behavioral measures within this policy set.

Financial Support: No financial support was received from any individual, institution, or organization for the conduct or publication of this study.

Conflict of Interest: There are no conflicts of interest regarding this study.

Ethics Approval: As the data used in this study are publicly available, no application to an ethics committee was required.

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