The Health Cost of Carbon: How Emissions, Urbanization, Life Expectancy and Economic Growth Shape Health Expenditures in BRICS Plus Countries

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ABSTRACT: This study investigates the linkages between carbon emissions, economic growth, life expectancy, urbanization, and health expenditure in the BRICS Plus countries for the time period 2000–2023. The study employs Balanced Panel data and Panel Econometric Methods to investigate the short-run and long-run relationship amongst selected variables. Panel Unit Root tests are used to test the stationarity of the data. Panel Cointegration tests are used to find out the long-run relationship between the variables. The study employs multiple estimation techniques such as FMOLS, DOLS, Panel ARDL-PMG, Fixed Effects, and Random Effects Models to achieve reliable results. The Hausman test is used to decide which estimation model is to be selected and preferred. The results show that the variables are in a stable long-run relationship with one another. The long-run results indicate that carbon emissions and life expectancy are not associated with health expenditure. Whereas economic growth is associated with health expenditure. The Error Correction Mechanism verifies that short-run changes move towards the long-run equilibrium. The Panel Regression results show that carbon emissions and urbanization are important factors affecting health expenditure.

KEYWORDS: BRICS Plus, FMOLS, DOLS, Panel ARDL-PMG, Fixed, Random

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Introduction

Health financing is one of the most important tools to improve the overall socioeconomic development of the country. Many governments and inter-governmental organizations are allocating their financial resources over time to improve the overall health care systems and increase the effectiveness of health care facilities, besides reducing the cost of different diseases. It is a fact that many factors, including demographic, environmental, and economic factors, are reasons behind the increase in overall health expenditures in different countries (Sabra, 2022). In addition, the most contributing factors behind this dilemma are economic growth, growing life expectancy, quick urbanization, and unexpected carbon emissions. The factors have become a center of attention for academics and industry. Because they have a significant contribution to overall growth and the demand for health services (Chen et al., 2021). Moreover, it is essential to explore what factors are and how they create an impact on health expenditure in order to

create effective public policy mechanisms, especially on the emerging trading in the BRICS Plus countries. At present time, climate change is the most menacing global problem for all countries irrespective of their economic strength. The most important reason behind this issue is the continuous growth of carbon emissions contributed by industrial production, the transport sector, energy-generating plants, and the rapid pace of urban development in different countries. The pathetic environment sustainability has highly affected people, particularly through diseases related to the respiratory system, cardiovascular system, heating and temperature system any many other diseases which are having serious consequences for human health and conditions (Lakocai, 2025). Furthermore, the relationship between environmental contamination and public health has attracted significant attention from the global community. Higher levels of carbon emissions often lead to increased air pollution, which negatively affects human health. Polluted air contains harmful particles and gases that can damage the lungs, heart, and other organs of the human body. It is prone to all age bracket people specially children and older people (Li et al., 2022). In response, countries facing higher amounts of carbon emissions often face a great burden of health costs. Consequently, the affected people are going to hospitals regularly to get medical treatment and health care facilities form the doctors. It means that the healthcare expenses are increasing at large. The stakeholders of different countries need to focus on to promote environment protection in order to reduce the overall health expenditures (Amin, 2024). Economic growth is another significant factor of health care expense. Furthermore, economic growth is also an important factor behind health expenditure. It is a common phenomenon that as economies grow, the overall per capita income rises. In response, governments raise more taxes, and investments in healthcare infrastructure are increased. People with higher incomes are able to afford more health care services, health insurance, and preventive care, as well as paying for medicines. Economically more robust governments also have more money to invest in hospitals, medical equipment, health workers, and disease prevention initiatives (Mehfooz et al., 2023). In results, this is a fact that economic growth increases, and the rate of spending on the health sector is also increasing. It means that the countries need more access to health care services as the living standard of the nation rises. But the relationship between economic growth and health spending is not always clear. Economic growth always leads to increased expenditure on health care, but can also lead to an improvement in social perspectives such as education, nutrition, sanitation, and access to medical technology, which can decrease the prevalence of some diseases over time (Cleopatra, 2020). In addition, there are likely to be variations in healthcare spending across countries with different levels of economic growth. In developing economies, economic growth can result in better access to basic healthcare services. While in developed countries, economic growth can be more associated with the increased availability of advanced medical technologies and specialized healthcare services (Hou, 2025). Therefore, the long-term effects of economic growth on health expenditure are still important in practical scenarios. Urbanization is also an important determinant of health expenditure. In the recent past, a major proportion of people have migrated from rural areas to cities in search of better employment opportunities, education, and improved living standards (Polcyn et al., 2023). In many countries, urbanization has played an important role in many aspects such as social and economic development, which in turn created a great impact on the expansion of industries and technological development (Guo et al., 2022). But the fast pace of urbanization poses serious challenges to health systems as well. The increasing population of cities puts a great strain on hospitals, clinics, sanitation and public health services. It has been proven that economic, demographic, and environment-related factors highly affect healthcare expenditure. First, carbon emissions are considered the most terrible challenge to public health due to environmental degradation. Second, economic growth affects healthcare investment. Third, urbanization is affecting healthcare needs due to the rapid growth of the population. Fourth, the growing life expectancy increases the overall demand for long-term medical facilities (Ridwan et al., 2026).

Problem Statement

Health is a crucial component of any country. But in many countries, there are issues in delivering improved health services. Population shifts, environmental issues, and economic shifts are driving up health spending. Carbon emissions are increasing in many developing countries. Excessive carbon emissions can cause health issues and require medical attention. Healthcare needs are also impacted by changes in life expectancy and fertility rates, which alter the population size and composition. An economy's capacity to spend more on health services can grow as a result of economic growth. But the impact of these factors on health expenditure remains unclear. The BRICS Plus countries are facing rapid changes in their economies, population, and environment. Better healthcare systems and sustainable health financing are needed in these countries. Most of the research to date has been on the impact of economic growth on health spending. The aggregate impacts of carbon emissions, life expectancy, fertility rate, and the different types of health expenditures such as public expenditure and private expenditure have received less attention from research experts and academicians. As a result, this research study investigates the impact of major determinants of health expenditure in the BRICS Plus countries.

Literature Review

BRICS Plus countries have faced a significant economic transformation, industrial development, urbanization, and population growth. The developments have brought benefits in terms of living standards and health care systems, but have also posed challenges on issues of environmental pollution, growing demands on health care, and growing health care costs (Ahmad et al., 2025). Explain how carbon emissions, economic growth, urbanization, life expectancy and health expenditure are related and the different theories that underpin the understanding of these complex relationships. Michael Grossman's Grossman Health Capital Theory is one of the most important theories regarding the relationship between income, health care investment and health outcomes. This theory takes the view that health is a type of capital which is used to enhance the quality of life for the individual and also to improve their productivity (Ahmad et al., 2023). Health investments are made by people and communities through health care, health care facilities, education, nutrition, and a healthy environment. The theory posits that with higher incomes, individuals and governments can allocate more resources to the improvement of health care. It is therefore hypothesized that economic growth will have a positive impact on health expenditure because of the increase in income, which will enable them to allocate more resources to hospitals, medical technology, healthcare infrastructure, and disease prevention programs. (Majekodunmi, et al., 2025). This theory is applicable to the economies of BRICS Plus countries because in the past decades, these economies have experienced tremendous economic development. Countries like China, India, Brazil, and Indonesia have enhanced their national income by industrialization, expansion in trade, and economic reforms. Increased income led to governments expanding health care programs and households demanding better health care services (Bilgili et al., 2021).

However, the Grossman Health Capital Theory also implies that an increase in income will increase health care spending, as well as the health of the people, because they will have access to better living conditions, education, and medical facilities. Therefore, direct and indirect impacts of economic growth on health expenditure can be possible (Ge & Wu, 2025). The Health Production Function Theory is another important theory that explains the relationship between environment, economy, and social determinants and health. In this theory, health results from the interaction of various inputs such as health services, income, education, environmental quality, lifestyle, and social conditions. There are other external factors that have an important role in health outcomes beyond expenditure on health care (Saleem et al., 2023). This theory reveals that a substandard environment and unhealthy living conditions can have a detrimental effect on the health of the population and increase the use of health care services.

Carbon emissions, urbanization, economic growth, and life expectancy are added as factors affecting health expenditure because they are justified by the Health Production Function Theory. Carbon emissions have a negative effect on environmental quality, such as air pollution and climate change. High levels of air pollution are a threat to respiratory and cardiovascular diseases and other health problems. As the threat of disease increases, more investment is needed in health care services by governments and individuals (He et al., 2026). As a result, carbon emissions could also lead to higher health care costs due to the extra health burden. The Environmental Kuznets Curve Theory describes the relationship between economic growth and environmental degradation. The theory assumes that pollution levels increase initially as a country develops its economy, as it is dependent on industrial processes, fossil fuels, and resource use in the initial stages of development (Munir, 2025). Once a certain threshold of economic development is achieved, however, countries can lower pollution by using modern technology, by setting environmental regulations, and by using cleaner energy sources.

The EKC Theory is applicable in the case of BRICS Plus countries. Because their economies are industrialized. China, India, and South Africa are numerous important economies, leading examples of countries that increased their carbon emissions by accelerating their production and energy consumption in the early stages of development. Economic growth did provide better employment and living standards, but also environmental problems (Islam & Baida, 2025). The EKC theory proposes that in the future, these countries can achieve better environmental results via renewable energy, energy efficiency, and better environmental policies. The EKC theory can also be applied to explain the carbon emissions and health expenditure relationship. Increased pollution levels may lead to greater health risks and add to health care costs (Hussain et al., 2023). For example, increased air pollution is linked to increased prevalence of respiratory diseases, potentially leading to increased use of medical care and health care resources. Economic growth without environmental protection can lead to higher expenditure on health care. This means that sustainable economic development is a key factor in reducing environmental health risks (Polat et al., 2025). Urbanization Theory is an analysis of the effects of the residential migration from rural to urban areas on economic activity, social services, and health. Urbanization is an important feature of the BRICS Plus countries, with millions of people moving to the cities for jobs, industrialization, and a higher standard of living. In general, hospitals, health care facilities, and medical practitioners are more developed in urban areas than in rural areas, as are modern technology and services. (Açıkgöz et al., 2026). Therefore, urbanization can be a means to improve access to health care and to improve health outcomes. But the Urbanization Theory also states that there can be adverse health impacts in rapid and unplanned urbanization. Cities with high population density can result in congestion, pollution, waste production, and pressure on public services. Poor urban planning can result in overcrowding, lack of health services, and a poor environment (Uddin et al., 2023). These issues can result in increased disease risks and health care costs. Thus, the impact of urbanization on health expenditure could be positive or negative depending on the quality of urbanization and government planning.

Demographic Transition Theory is an explanation of the changes in the structure of population in countries during their economic and social development (Bi & John, 2026). This theory suggests that as countries' health care, education, and living conditions improve, their birth rates and death rates go down. Demographic transition is associated with a number of important outcomes, one of which is life expectancy and population ageing. Life expectancy also has an impact on healthcare expenditure because a longer life will need more healthcare services. The older population generally requires greater health care due to chronic diseases, long-term illness, and age-related health problems (Ramos et al., 2023). Therefore, a rise in life expectancy can place further strains on health care systems. This relationship is particularly significant for countries of the BRICS Plus, where many of its members are undergoing demographic changes. China and Russia are facing population ageing; for other countries such as Brazil and Indonesia, there is also a population structure change (Georgescu et al., 2025). Governments need to put more

investment in healthcare services, elderly care programs, and disease management, as the elderly population is increasing. Demographic Transition Theory can explain how life expectancy can impact the spending on healthcare (Yılmaz & Ozaner, 2025). The theory of Sustainable Development provides a more holistic perspective on the linkage between economic development, environment, and human health. The concept of this theory is that development should not be at the expense of the ability of future generations to develop (Tanha et al., 2026). From a development point of view, development should be achieved without destroying natural resources, pollution should be minimized, and social welfare should be enhanced. Sustainable development is especially relevant to the BRICS Plus countries, which are expected to keep expanding their economies, but in a way that does not harm the environment. (Soontha & Bhat 2023). High emission levels and degradation can cause long-term health issues and higher health expenditure. Implementing sustainable development measures, such as the use of renewable energy, green technologies, and sustainable urban planning, can help to mitigate pollution and enhance public health (Sohail et al., 2023). The theory implies that there is a close relationship between environmental protection and improvement of health services. Lowering carbon emissions will help to improve air quality, lower the number of diseases caused by pollution, and lower the burden of health care. Similarly, sustainable economic development can provide financial resources to improve health care (Lengos & Dritsaki, 2026). Therefore, sustainable development provides a comprehensive overview in understanding the interconnections between environmental quality, economic growth, and health expenditure. Overall, these theories provide strong theoretical foundations to investigate the determinants of health expenditure in BRICS Plus countries (Khine et al., 2026).

The Grossman Health Capital Theory provides an explanation for the growth of economic activity and its impact on the demand for health services and the investment in health services. The Health Production Function theory emphasizes that health outcomes are shaped by various factors, including environmental and socioeconomic factors (Yang et al., 2024). The Environmental Kuznets Curve Theory is the theory that relates economic growth and carbon emissions. Urbanization Theory it is related urban growth to access to healthcare and health issues. Aging populations and increasing life expectancy are important factors of Demographic Transition Theory in relation to healthcare needs (Akram et al., 2025). Sustainable Development Theory is the theory of balancing economic development, environmental protection, and human health. These supporting theories have proved that economic, environmental, and demographic factors all influence health expenditure in BRICS Plus countries. Economic growth can increase the capacity for health care and increase the demand for health care, and environmental health risks can increase the cost of health care (Bashir et al., 2025). The urbanization process increases access to health services, but also generates environmental issues. An increase in life expectancy is a sign of development, but also creates new health care difficulties. Therefore, it is important to understand the relationship to analyze the impact of carbon emissions, urbanization, life expectancy and economic growth on health expenditure in the BRICS Plus countries (Hamdi et al., 2025).

Data Estimation Methods

The quantitative research methodology is used in this research to investigate the role of carbon emissions, economic growth, life expectancy, and urbanization as the main determinants of health expenditure in BRICS Plus countries. The study employs balanced panel data for ten BRICS Plus economies: Brazil, Russia, India, China, South Africa, Egypt, Ethiopia, Iran, the United Arab Emirates, and Indonesia for the 2000-2023 period. The secondary data are gathered from internationally accepted databases, that is, World Development Indicators (WDI). The empirical analysis starts with the tests of stationarity properties of variables using panel unit root tests such as Levin–Lin–Chu (LLC), Im–Pesaran–Shin (IPS), Augmented Dickey–Fuller (ADF), Fisher and Phillips–Perron (PP) Fisher tests.

The Pedroni approach is used to perform panel cointegration analysis to determine the long-run equilibrium relationships between the variables. The study uses panel regression analysis such as Pooled OLS, Fixed Effects and Random Effects models, and the Hausman specification test is applied to determine the most suitable model. In addition, Panel ARDL–PMG, Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) estimators are used to explore the long-run and short-run relationships.

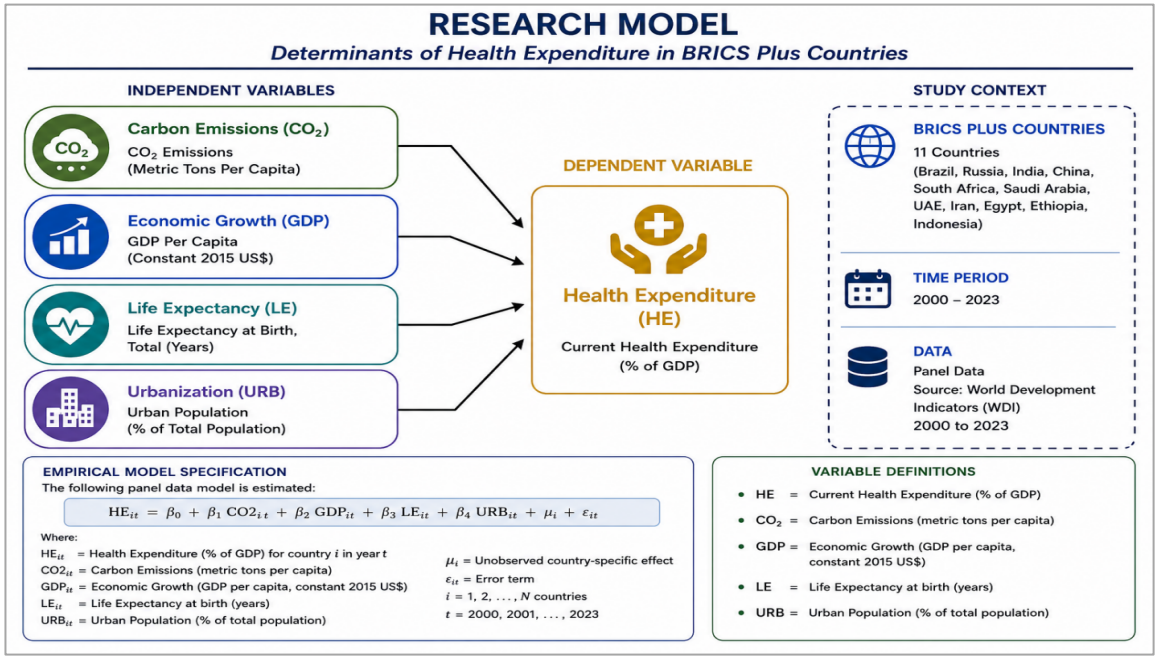
Description of Selected Variables

Table 1

Variables	Type	Operational Definition	Measurement & Source
Health Expenditure (HE)	Dependent Variable	Total current health expenditure incurred by public and private sectors for the provision of healthcare services and goods.	Current Health Expenditure (% of GDP). World Development Indicators (WDI), World Bank
Carbon Emissions (CO_2)	Independent Variable	The amount of carbon dioxide emitted into the atmosphere as a result of fossil fuel combustion and industrial activities.	CO_2 Emissions (Metric Tons Per Capita). World Development Indicators (WDI), World Bank
Economic Growth (GDP)	Independent Variable	The increase in a country's economic output and income over time, reflecting improvements in economic performance and living standards.	GDP Per Capita (Constant 2015 US$). World Development Indicators (WDI), World Bank
Life Expectancy (LE)	Independent Variable	The average number of years a newborn infant is expected to live under prevailing mortality conditions.	Life Expectancy at Birth, Total (Years). World Development Indicators (WDI), World Bank,
Urbanization (URB)	Independent Variable	The proportion of a country's total population residing in urban areas, reflecting the level of urban development and population concentration.	Urban Population (% of Total Population). World Development Indicators (WDI), World Bank

Source: World Development Indicators (WDI)

Research Model



Source: Author's Own Model

Table 2

Panel Unit Root Tests

Variables	Levin, Lin & Chu (LLC) Test	ADF-Fisher Chi-Square Test	PP-Fisher Chi-Square Test	Order of Stationarity
	Statistics	P-Values	Statistics	P-Values
Carbon Emissions	-5.5878	0.0000	77.8531	0.0000
GDP	-3.0804	0.0010	47.0333	0.0006
Health Expenditure	-10.2435	0.0000	122.3770	0.0000
Life Expectancy	-6.0082	0.0000	120.3230	0.0000
Urbanization	-2.9869	0.0014	42.5665	0.0023

Source: Author's Own Calculations

The results of the Panel Unit Root test using the Levin, Lin and Chu (LLC) and ADF-Fisher Chi-square tests are presented in the table. The tests were used to check the stationarity of the panel variables and to identify the order of integration of each variable. The results show that all variables are stationary after first differencing. The LLC test gives negative and statistically significant statistics for all variables with P-values < 1%. Thus, all variables are rejected as having a unit root. The ADF-Fisher Chi-square test also confirms these results with statistically significant Chi-square statistics at the 1% level for all variables. The stationarity of the panel series in their first differences and the same order of integration is supported by the consistency of the LLC and ADF-Fisher tests. All variables are stable in the 1st difference, and there is no evidence of a 2nd difference, which means that the data satisfy all preconditions for panel cointegration analysis.

Table 3

Pedroni Residual Panel Cointegration Test

Test Statistics	Statistics	Prob
Within-Dimension (Panel Statistics)		
Panel V-Statistics	-2.5709	0.9949
Panel RHO-Statistics	0.7124	0.7619
Panel PP-Statistics	-0.9425	0.1730
Panel ADF-Statistics	-0.7158	0.2371
Between-Dimension (Group Statistics)		
Group RHO-Statistics	1.5493	0.9393
Group PP-Statistics	-2.2102	0.0135
Group ADF-Statistics	-4.1678	0.0000

Source: Author's Own Calculations

The Pedroni Residual Panel Cointegration test is used to test for a long-run equilibrium relationship between health expenditure, carbon emissions, economic growth, life expectancy, and urbanization in the BRICS Plus countries. The results are inconclusive in the various Pedroni statistics. The within dimension statistics are statistically insignificant: Panel V-Statistic (P=0.9949), Panel RHO-Statistics (P=0.7619), Panel PP-Statistics (P=0.1730), and Panel ADF-Statistics (P=0.2371). The results do not reject the null hypothesis of no cointegration, indicating that the within-panel estimators do not offer enough evidence of a long-run relationship. The Between-Dimension-Group Statistics. However, are more supportive of cointegration. The Group PP-Statistic is significant at the 5% level (P=0.0135), and the Group ADF-Statistic is highly significant at the 1% level (P=0.0000), which means that the null hypothesis of no cointegration is rejected. The Group RHO-Statistic (P=0.9393) is not significant, but the

significant Group PP and Group ADF statistics give strong evidence of a stable long-run equilibrium relationship between the variables. The results are reliable for heterogeneous panels like the BRICS Plus countries because the group statistics of Pedroni are based on the heterogeneity of the cross-sectional units. Thus, it is concluded that the study variables are cointegrated in the long run, and therefore the Panel ARDL-PMG, FMOLS, and DOLS are used to estimate the long-run coefficients.

Table 4

Fully Modified Ordinary Least Squares (FMOLS)

Variables	Coefficients	St Error	T-States	Prob
Carbon Emissions	0.0904	0.1371	0.6598	0.5101
GDP	-0.5087	0.1347	-3.7777	0.0002
Life Expectancy	0.3198	0.4230	0.7560	0.4504
Urbanization	0.9367	0.4125	2.2710	0.0241

Source: Author's Own Calculations

The Fully Modified Ordinary Least Squares (FMOLS) estimation method is used to analyze the long-run impacts of carbon emissions, economic growth, life expectancy, and urbanization on health expenditure in the BRICS Plus countries. The results show that the coefficient of Carbon Emissions is positive (β=0.0904) but statistically insignificant (P=0.5101), which means that the long-run effect of Carbon Emissions on health expenditure is not significant. The coefficient (β) of Economic Growth (GDP) is negative and statistically significant (β=–0.5087, P=0.0002), which means that for every unit increase in GDP, health expenditure decreases by 0.5087 units, while other factors remain constant. This discovery indicates that increased economic growth can enhance the efficiency of healthcare, living standards, and preventive healthcare, which can lead to lower long-term healthcare costs. Life Expectancy has a positive coefficient (β = 0.3198) but is not statistically significant (P=0.4504), meaning that it does not significantly influence health expenditure in the long run. On the other hand, Urbanization has a positive and statistically significant coefficient (β=0.9367, P=0.0241), which indicates that the higher the urbanization, the higher the health expenditure in BRICS Plus countries. This outcome could be attributed to the increasing demand for health infrastructure, medical services, and public health facilities due to urbanization. In general, the results of the FMOLS indicate that the factors that affect health expenditure in the long run are Economic Growth and Urbanization, while Carbon Emissions and Life Expectancy do not have a statistically significant long-run effect.

Table 5

Dynamic Ordinary Least Squares (DOLS)

Variables	Coefficients	St Errors	T-States	Prob
Carbon Emissions	0.9354	0.6443	1.4517	0.1502
GDP	-0.9634	0.5418	-1.7782	0.0789
Life Expectancy	4.0807	1.9432	2.1000	0.0387
Urbanization	-2.6677	1.7395	-1.5337	0.1288

Source: Author's Own Calculations

The Dynamic Ordinary Least Squares (DOLS) results provide an explanation of the long-run impact of carbon emissions, GDP, life expectancy, and urbanization on health expenditure in the BRICS Plus countries. The coefficient of carbon emissions is positive (0.9354), suggesting that a rise in environmental pollution is likely to lead to an increase in health expenditure, as there may be health risks linked to a rise in environmental pollution. The relationship is not statistically significant (P=0.1502), however, indicating that carbon emissions do not have a strong long-run influence on health expenditure in the model. The coefficient of GDP is negative (-0.9634) and statistically

insignificant (P=0.0789). This suggests that economic growth does not have a significant impact on health expenditure in the long run, but that there may be a relationship between economic conditions and health allocation. The results indicate that life expectancy has a positive and statistically significant relationship with health expenditure, with a coefficient of 4.0807 and a probability value of 0.0387. This means that the gains in life expectancy lead to higher demand for health care and higher expenditure on health care. On the other hand, urbanization has a negative coefficient (-2.6677) but is not statistically significant (P=0.1288), meaning that urban population growth does not significantly influence health expenditure. Overall, the DOLS results validate that among the selected variables, life expectancy is the most important long-run factor of health expenditure.

Table 6

Panel ARDL-PMG Long-Run

Variables	Coefficients	St Errors	T Statistics	Prob
Carbon Emissions	-0.3204	0.1034	-3.0987	0.0023
GDP	0.4287	0.1922	2.2304	0.0270
Life Expectancy	-4.2211	1.0083	-4.1865	0.0000
Urbanization	0.3454	0.4354	0.7934	0.4286

Source: Author's Own Calculations

The Panel ARDL-PMG long-run estimation results indicate that there is a long-run relationship between carbon emissions, GDP, life expectancy, urbanization, and health expenditure in the BRICS Plus countries. The results show that carbon emissions have a negative and statistically significant effect on health expenditure, with a coefficient of -0.3204 and a probability value of 0.0023. This indicates that there is a negative relationship between carbon emissions and health expenditure in the long run, which may be due to the fact that there are different environmental health policies and resource allocation across countries. The coefficient of GDP is positive (0.4287) and statistically significant (P=0.0270), suggesting that economic growth is associated with an increase in health expenditure. This means that better economic performance increases the capacity of the government and household resources to invest more in health services. The results reveal that life expectancy has a negative and highly significant effect on health expenditure, with a coefficient of -4.2211 (P= 0.0000). This implies that countries with higher life expectancy will have lower growth in health expenditure because of better health conditions, preventive health systems, and better living standards. On the other hand, urbanization has a positive coefficient (0.3454) with a P-value of 0.4286, which is not statistically significant, suggesting that the long-run effect of urban population growth on health expenditure is not meaningful. The results overall indicate that GDP and life expectancy are important factors in health expenditure in the BRICS Plus countries.

Table 7

Panel ARDL-PMG Short Run

Variables	Coefficients	St Errors	T Statistics	Prob
Error Correction Term (COINTEQ01)	-0.2806	0.1096	-2.5600	0.0113
Carbon Emissions	-0.3426	0.2687	-1.2747	0.2041
GDP	-0.7232	0.3023	-2.3927	0.0178
Life Expectancy	0.8256	0.6126	1.3476	0.1795
Urbanization	-6.2004	3.6298	-1.7082	0.0894
Constant	4.2186	1.6321	2.5848	0.0106

Source: Author's Own Calculations

The Panel ARDL short-run results provide an explanation of the immediate impact of carbon emissions, GDP, life expectancy, and urbanization on health expenditure in the BRICS Plus countries. The error correction term (COINTEQ01) is negative (-0.2806) and statistically significant (P=0.0113), which indicates that there is a long-run equilibrium relationship between the variables. The coefficient shows that about 28.06% of the short-run deviations from the long-run equilibrium are corrected in each period, indicating a slow adjustment process towards the long-run equilibrium. The coefficient of carbon emissions is negative (-0.3426) but not statistically significant (P=0.2041), indicating that the short-run effect of environmental pollution on health expenditure is not significant. The coefficient of GDP is negative and statistically significant at the 1% level (-0.7232, P= 0.0178), suggesting that a short-term increase in economic growth is correlated with a decrease in health expenditure in the countries under study. The effect of life expectancy is positive (0.8256) but not statistically significant (P=0.1795), suggesting that an increase in life expectancy does not immediately affect health spending. Rapid urbanization has a negative coefficient (-6.2004) and is marginally insignificant (P=0.0894), suggesting that rapid urbanization may impose short-run pressures on the allocation of healthcare. The large positive constant (4.2186) suggests that there are other factors that affect the changes in health expenditure in the short run. Overall, the short-run results indicate that GDP is the only important factor affecting health expenditure.

Table 8

Panel Fixed Effect Model

Variables	Coefficients	St Errors	T Statistics	Prob
Carbon Emissions	-0.5293	0.1196	-4.4273	0.0000
GDP	0.1308	0.0975	1.3419	0.1810
Life Expectancy	0.6416	0.3973	1.6149	0.1077
Urbanization	0.5021	0.1234	4.0698	0.0001
Constant	-3.7827	1.6233	-2.3303	0.0207

Source: Author's Own Calculations

The Panel Fixed Effect Model results analyze the effect of carbon emissions, GDP, life expectancy, and urbanization on health expenditure, taking into account country-specific features in the BRICS Plus countries. The results show that health expenditure is negatively and significantly affected by carbon emissions with a coefficient of -0.5293 and a probability value of 0.0000. This indicates that there is a negative relationship between carbon emissions and health expenditure, which may be due to differences in environmental management, health priorities, and policy responses across countries. The coefficient of GDP is positive (0.1308) but not statistically significant (P=0.1810), suggesting that the direct effect of economic growth on health expenditure is not significant in the Fixed Effect Model. Likewise, there is a positive coefficient (0.6416) for life expectancy, indicating that an increase in life expectancy can lead to an increase in the demand for healthcare, but this is not statistically significant (P=0.1077). The results show that health expenditure is positively and highly significantly influenced by urbanization with a coefficient of 0.5021 and a probability value of 0.0001. This means that as the urban population grows, so does the spending on healthcare, as there is more demand for medical facilities and healthcare services in urban areas. The constant is negative and significant, indicating the effect of other factors not included in the model. In general, the Fixed Effect results highlight the importance of carbon emissions and urbanization in accounting for the differences in health expenditure between the BRICS Plus countries.

Table 9

Model Statistics

Statistics	Values
R-Squared	0.8418
Adjusted R-squared	0.8327
F-Statistics	92.4735
Prob(F-Statistics)	0.0000
Observations	240
Countries	10

Source: Author's Own Calculations

The Panel Fixed Effect Model Statistics show that the estimated model has a high explanatory power in explaining the variation in health expenditure between the BRICS Plus countries. The R-squared value of 0.8418 indicates that the overall model accounts for about 84.18% of the variance in health expenditure, with the remaining variance being explained by other factors not captured in the model. The adjusted R-squared value of 0.8327 is a good value given the number of explanatory variables used in the model. The small difference between R-squared and adjusted R-squared suggests that the variables chosen are significant in explaining health expenditure but not too many irrelevant variables are included. The overall model is statistically significant at the 1% level with an F-statistic value of 92.4735 and a probability value of 0.0000. This shows that the independent variables are jointly significant in explaining health expenditure, which supports the use of the Fixed Effect Model in panel data analysis. The analysis is based on 240 observations from 10 countries, which is adequate for reliable estimation across countries and over time. In general, the model statistics indicate that the Panel Fixed Effect Model is a good fit and is able to capture the determinants of health expenditure in the BRICS Plus countries.

Table 10

Panel Random Effect Model

Variables	Coefficients	St Errors	T Statistics	Prob
Carbon Emissions	-0.3498	0.0967	-3.6179	0.0004
GDP	0.0492	0.0877	0.5615	0.5750
Life Expectancy	0.4168	0.3857	1.0808	0.2809
Urbanization	0.5118	0.1197	4.2767	0.0000
Constant	-2.3719	1.5378	-1.5424	0.1243

Source: Author's Own Calculations

The Panel Random Effect Model results examine the effect of carbon emissions, GDP, life expectancy, and urbanization on health expenditure in the BRICS Plus countries, taking into account country-specific Random Effects. The results show that carbon emissions have a negative and statistically significant effect on health expenditure, with a coefficient of -0.3498 and a probability value of 0.0004. This suggests that higher carbon emissions are linked to lower health spending, which could suggest that environmental issues have an impact on health spending and resource management. The coefficient of GDP is positive (0.0492) but not statistically significant (P=0.5750), suggesting that there is no significant direct effect of economic growth on health expenditure in the Random Effect Model. Likewise, life expectancy has a positive coefficient (0.4168), suggesting that higher life expectancy could lead to greater healthcare needs, but this is not statistically significant (P=0.2809). The results show that urbanization has a positive and highly significant effect on health expenditure, with a coefficient of 0.5118 and

a probability value of 0.0000. This indicates that the more urbanized a region is, the more it will spend on healthcare facilities, services, and health infrastructure because of the increased demand for healthcare services. The constant term is negative (-2.3719) but not statistically significant (P=0.1243). Overall, the Random Effect results indicate that carbon emissions and urbanization are important factors affecting health expenditure in the expanded BRICS Plus countries.

Table 11

Model Statistics

Statistics	Values
R-Squared	0.1118
Adjusted R-Squared	0.0967
F-statistic	7.3984
Prob(F-Statistics)	0.000013
Durbin-Watson Statistics	0.4022
Observations	240
Cross-sections	10

Source: Author's Own Calculations

The model statistics of the Panel Random Effect Model show the overall performance and reliability of the estimated model for the determinants of health expenditure in the BRICS Plus countries. The R-squared value of 0.1118 indicates that about 11.18% of the variability in health expenditure can be accounted for by the four variables included in the model: carbon emissions, GDP, life expectancy, and urbanization, while the rest of the variability is due to other factors not included in the model. The adjusted R-squared value of 0.0967 is a confirmation of the explanatory power of the model after adjusting for the number of independent variables included. The overall F-Statistic value is 7.3984 with a probability value of 0.000013, which means that the model is statistically significant. This indicates that the explanatory variables have a significant effect on health expenditure together, and the random-effects specification gives meaningful results for panel data analysis. The analysis is based on 240 observations in 10 cross-sectional countries, giving a balanced panel structure for estimation. The Durbin–Watson statistic value of 0.4022, however, is relatively low, suggesting that there may be positive serial correlation in the residuals. This indicates that the model errors might have time-related patterns and should be taken into account when interpreting the results. The overall statistical significance of the Panel Random Effect Model suggests that there are important relationships between the determinants selected, but the lack of explanatory power and the presence of possible autocorrelation suggest that further diagnostic tests and robust estimation methods may be needed.

Table 12

Hausman Test

Tests	Chi-Square Statistics	Degrees of Freedom	Prob
Cross-section Random Effects	7.8715	4	0.0964
Random Model is Selected			

Source: Author's Own Calculations

The Hausman test is used to select the best model specification between the Panel Fixed Effect Model and the Panel Random Effect Model. The null hypothesis of the Hausman test is that the Random Effect Model is appropriate, and the alternative hypothesis is that the Fixed Effect Model is more appropriate because there is correlation between individual effects and explanatory variables. The results show a Chi-Square Statistics Value of 7.8715 with 4 Degrees of Freedom and a Probability value of 0.0964. Since the probability value is greater than the 5% significance level

($p > 0.05$), the null hypothesis cannot be rejected. This means that the Fixed Effect and Random Effect estimation are not significantly different. Hence, the Panel Random Effect Model is chosen as the most suitable model for the analysis of the relationship between carbon emissions, GDP, life expectancy, urbanization, and health expenditure in the BRICS Plus countries. The choice of the Random Effect Model suggests that the country-specific effects are Random and that they are not significantly related to the explanatory variables in the model. In general, the Hausman test supports the Random Effect specification as the more efficient and suitable estimation method for the panel data of 10 countries and 240 observations. The results of the Random Effect Model can thus be interpreted for policy implications on the determinants of health expenditure.

Conclusion

The empirical results offer a comprehensive explanation about the relationship amongst carbon emissions, economic growth, life expectancy, urbanization, and health expenditure in the BRICS Plus economies. The results are interpreted by the estimated coefficients: If the coefficient of an explanatory variable is positive, then an increase in the explanatory variable will increase the health expenditure, while keeping other factors constant; if the coefficient of an explanatory variable is negative, then an increase in the explanatory variable will decrease the health expenditure, while keeping other factors constant. The panel unit root test results show that all variables, such as health expenditure, carbon emissions, GDP, life expectancy, and urbanization, are stationary after first differencing. This means that all variables are 1st difference. The data are appropriate for the long-run analysis as none of the variables are integrated at the second difference level; thus, the data are suitable for cointegration and Panel ARDL-PMG techniques. The results confirm the stability of the statistical properties of the variables and their suitability for the analysis of the long-run determinants of health expenditure in the BRICS Plus countries. The Pedroni panel cointegration results suggest that there is a long-run relationship between health expenditure and its explanatory variables. The significant Group PP-Statistics (P=0.0135) and Group ADF-Statistics (P=0.0000) suggest that carbon emissions, GDP, life expectancy, and urbanization are co-moving over time with health expenditure. This means that changes in these economic, environmental, and demographic indicators have long-term implications for health care spending in the economies chosen.

The FMOLS results indicate that an increase of 1% in carbon emissions will result in an increase of 0.09% in health expenditure, which is not statistically significant. This means that the health expenditure in the FMOLS estimation does not increase significantly due to environmental pollution. The results indicate that carbon emissions may increase health risks, but the effects on health care costs will differ across countries based on the extent of health care availability, environmental policies, and government responses. The results of the FMOLS also indicate that a 1% rise in GDP leads to a reduction in health expenditure of around 0.51%. This negative correlation indicates that economic growth could enhance the quality of life, health system efficiency, prevention and population health, which would decrease the need for increased health spending. But this is not the conventional relationship, and it could be a result of the economic structures and investment priorities in healthcare of the BRICS Plus economies. The FMOLS results also show that the increase in urbanization by 1% raises health expenditure by around 0.94%. The urbanization process also increases the demand for health care services due to improved access to health care, increased utilization of hospital and medical facilities, and increased demand for sophisticated health care technologies. Hence, urbanization is an important factor influencing healthcare spending. The DOLS estimation provides additional evidence in the long run. According to the results, a 1% increase in life expectancy increases health expenditure by approximately 4.08%. This means that the longer people live, the more healthcare they will

need, as they will need more medical services, more chronic disease care, more elderly care, and more ongoing healthcare support.

The finding confirms that demographic changes play an important role in determining healthcare costs. The long-run results of the Panel ARDL are the key evidence of the study. The findings indicate that a 1% increase in carbon emissions is accompanied by a 0.32% reduction in health expenditure. This connection may appear paradoxical, but it suggests that there is no direct correlation between the increase in emissions and the increase in health expenditure, since there are differences in the health system, environmental management, and institutional capacity. Pollution-related health problems can result in increased disease burden in some larger BRICS Plus economies without an increase in health expenditure. The ARDL-PMG results show that a 1% rise in GDP leads to a rise in health expenditure by around 0.43%. This discovery is consistent with the notion that economic growth enhances the financial resources of governments and households, enabling them to invest more in health services. The more money, the more investment in hospitals, medical infrastructure, health technology, and health insurance systems. The results also reveal that an increase in life expectancy is associated with a reduction in health expenditure of approximately 4.22% in the long run. This implies that the gains in longevity could be due to healthier populations, better preventive health care systems, better living conditions and more efficient health care delivery systems, all of which lower health care costs. Thus, the increase in life expectancy in larger BRICS Plus countries could be due to better health rather than just ageing. The ARDL-PMG results indicate that health expenditure rises by around 0.35% per 1% rise in urbanization, but the relationship is not statistically significant. This means that urbanization could lead to higher demand for health services due to higher population density and utilization of health services, but the impact is not statistically significant in the long-run model. The short-run ARDL-PMG results show that the error correction coefficient is negative and significant (ECT=-0.2806), which implies that about 28% of the short-run deviations from the long-run equilibrium are corrected annually. This means that there is a consistent relationship between the variables that adjusts. The short-run impacts of a 1% rise in GDP on health expenditure are approximately -0.72%, while the short-run impacts of carbon emissions and life expectancy are not statistically significant. The short-run relationship between urbanization is negative; that is, a short-term increase in urbanization might not automatically result in an increase in health expenditure.

The Fixed Effects Model also provides additional evidence that an increase in carbon emissions of 1% results in a decrease in health expenditure of 0.53% and an increase in urbanization of 1% results in an increase in health expenditure of 1%. The R-squared value is high (0.8418), which shows that the selected variables account for about 84% of the variation in health expenditure in BRICS Plus countries. The same results are seen in the Random Effects Model. The results indicate that an increase in carbon emissions by 1% results in a reduction in health expenditure of approximately 0.35%, and an increase in urbanization by 1% results in an increase in health expenditure of approximately 0.51%. The Hausman test is used to test the Random Effects Model, which is supported by the test results, indicating that country-specific differences should be taken into account when explaining the differences in healthcare expenditure. The empirical findings show that economic growth, environmental factors, and demographic change have a significant impact on health expenditure in the BRICS Plus economies as a whole. Economic growth and urbanization tend to increase health expenditure as a result of increased demand for health services and increased access to health care in general. The results indicate that carbon emissions are negatively associated with health expenditure in most models, indicating that the environmental impacts are related to institutional and healthcare system characteristics. Life expectancy has a dual impact, as an increase in life expectancy not only leads to greater demand for health care services but also contributes to improvements in health care efficiency.

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