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Determinants of Life Expectancy in SAARC Countries: An Integrated Environmental and Socioeconomic Perspective

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Abstract

Environmental health is one of the determinants of human health, where pollution and degradation of the environment are major contributors to lifespan and health care. Among the countries of SAARC, there are cause of concern patterns - high rates of urbanization and altered economics and poor health infrastructure- that act in combination to amplify exposure to pollution-related health risks. This paper questions the knowledge in the nexus between environmental changes, socioeconomic growth, and the provision of services to people in later life expectancy in the SAARC economies through the 2000-2024 period. The analysis explains bi-directional relationships (the long-run equilibrium) between the dependent and the independent, along with short-run dynamics, using complex panel econometric methods (which include predominantly cross-sectional dependence tests, cointegration tests, and the Cross Belgrano Augmented Autoregressive Distributed Lag, or CS-ARDL) framework. Ecological implications, empirical evidence indicates that carbon dioxide emissions, the Division of standard and ecological influence on life expectancy have shown a significant adverse impact in the medium and long term, and thus support the negative health impacts of environmental degradation. To the contrary, economic growth, urbanization, and the level of provision of sanitation services, health spending turn into statistically significant positive factors concerned with life expectancy, and undernourishment and unemployment remain as negative factors. The short-run outcome indicates that when growth increases faster, it has short-run returns on health, but the side effects of pollution grow in significance when the horizon is long. These findings guide the construct as multi-faceted as health determinants in SAARC, in which the economic and social policies engage environmental conditions in a non-linear way. Finally, the paper will argue that sustainable gains in life expectancy will necessitate coherent strategies that would entail not only managing pollution, reinforcing the health and sanitation system integrity, and mitigating food insecurity and unemployment, but also making the development patterns eco-friendly and inclusive.

Keywords: *Environmental Quality, Life Expectancy, Health Determinants, SAARC Economies*

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1. INTRODUCTION

Environmental quality refers to the entire condition of the natural as well as manmade milieus, and it is expressed through indicators including atmospheric purity, aquatic purity, climatic sustainability, and ecosystem sustainability, all of which have a serious and significant impact on human wellbeing. This is a multi-dimensional construction that is shaped by a combination of biophysical and socio-political aspects (Kamp et al., 2003; Arshi et al., 2025). Air pollution is one of the most pernicious threats to the environment and has been stringently identified with adverse health consequences, especially respiratory and cardiovascular morbidity (Kassomenos et al., 2012). The rise in industrial development, overcrowding in

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cities, and high population growth have all contributed to the fueling of environmental degradation in the past decades. Such trends have not only triggered a decline in air quality but also high spikes in greenhouse gas emissions- prime instigators of climatic perturbation (Yazdi & Shakouri, 2014; Batool et al., 2025). As empirical evidence shows, the decline in the state of the environment is also associated with low levels of life expectancy and high rates of morbidity and early mortality (Zhong et al., 2022; Liu et al., 2023; Imran et al., 2021; Naeem et al., 2025).

Socioeconomically speaking, health plays a central role as a factor in determining the productivity of labor and hence the overall macroeconomic development. An increase in the quality of health is highly correlated with an increase in healthcare investment and high claims of environmental regulation (Sirag et al., 2016; Ali et al., 2025). Physiological loading factors comprise exposure to carbon dioxide (CO2), sulfur dioxide (SO2), and finer particulate matter (PM2.5), but also afflict cognitive and psychological performance, suggesting that it presents major concerns when considering the overall welfare of the population in the long term (Liu et al., 2023; Imran et al., 2024; Longston et al., 2025). Although the nexus between environmental degradation and outcomes in health is well-recognized, it is hard to measure resulting health impacts, more so in low-income and developing settings. Numerous African countries do not have structured and efficient environmental monitoring systems, and a lack of data often compromises the quality of health services delivery and climate-health association in these contexts (Mutizwa & Makochekanwa, 2015; Ali et al., 2025). In this regard, it is urgent to impose stricter control over the management of the environment and to ensure infrastructure investments focus directly on the rights of people, allowing for to reduction of the negative influence of degradation and enhancing the quality of life (Ali et al., 2025).

Air pollution has risen to become an urgent environmental issue that has a profound impact on morbidity and premature mortality, with a high effect on the low- to middle-income economies. According to World Health Organization estimates, recent it would not be an exaggeration to say that ambient air pollution has been taking over 6.5 million lives every year, and the insanely high death burden would disproportionately fall on children and the elderly (Leung and Matsui, 2025; Ali et al., 2025; Audi et al., 2025) The high rate of environmental change through urbanisation, transport, and industrial growth has worsened past respiratory disorders like asthma and chronic obstructive pulmonary disease especially in susceptible communities. The high air pollution levels, as the example of smog appeared in many Asian megacities, have increased the interest in the harmful impacts of environmental degradation on human health (Nakao et al., 2019). These phenomena highlight the importance of systematic interventions that would protect the quality of outdoor and indoor air quality. It is also evidenced that the effect of environmental crisis would be toned down due to increased spending on health because more people would access care, and chances of diseases caused by pollution would be decreased (Nathaniel & Khan, 2020; Marc et al., 2025). It is important to improve the healthcare system, particularly in risk zones, to reduce mortality and increase life expectancy. The 1992 Earth Summit was critical in bringing out the interconnectedness between the quality of the environment and human health, and sustainable development. It highlighted that environmental degradation, such as loss of biodiversity and disruption of an ecosystem (along with ecosystems), represents a serious threat on a national and international scale (Ullah et al., 2020; Marc et al., 2025). Though the quality of the outdoor air has been a major policy area of concern, concerns about indoor air quality (IEQ) have increasingly risen as people spend most of their time inside.

Various health issues, such as respiratory disease, asthma, and neurological impact, have been attributed to poor IEQ due to insufficient ventilation, indoor pollutants, or even poor building construction (Ali et al., 2023; Marc & Ali, 2023; Leung and Matsui, 2025). The effects are most eminent in children, the aged, and people with pre-existing conditions. The concept of overcoming the IEQ issue must be targeted through a comprehensive approach based on the housing policy, urban planning, and public health. Educational programs to sensitize the masses can create habits that help bring clean indoor conditions, and more stringent building codes and better ventilation levels could help save more health consequences of interiors pollution. It is, therefore, not the comfort issue solely; the improvement of the quality of the indoor environment is a political issue because of the influence of its social and economic outcomes. The unremitting population increase in the world puts more strain on natural resources, hence reducing environmental degradation. The pressing nature of environmental stewardship can be illustrated by unsustainable use of ecosystems, such as overuse of energy, overextraction of natural resources, and poor management of waste. Public awareness and education are not (therefore) necessary to help combat environmental challenges. Through environmental education that prepares the citizens with the needed information and the sense of responsibility, individual citizens can change their daily behaviors to be cleaner and more sustainable, and in the process improve the environmental as well as personal health conditions (Short, 2009; Marc & Ali, 2017; Senturk & Ali, 2021). Multi-level governance and taking action on environmental concerns are another critical approach that is necessary at a place level and at an international level. Both air and water, and indoor air pollutants, present a significant risk to human health. Air pollution sources like fine particulate emissions and noise, as well as insufficient availability of clean water and sanitation, are linked with a wide range of illnesses, especially in high-risk populations such as children, the elderly, and households with low income (Evans and Kantrowitz, 2002; Ali & Audi, 2016). The inequalities associated with socio-economics further aggravate the vulnerability to environmental threats, since underprivileged groups are usually located in places with no environmental facilities and with no access to health care facilities, thus compromising the health at large. Reducing environmental health risks thus requires redress towards inequality and poverty.

Sustainable development models provide a balanced approach to the amelioration of environmental and human health outcomes. The inseparability of health conditions and ecological situations is not something new to organizations like the

World Health Organization. In the last fifty years, the WHO has come up with Environmental Health Indicators (EHI) to follow and improve the environmental determinants of health, such as air quality, sanitation, and water safety (Kjellström and Corvalan, 1995; Ali & Ahmad, 2014; Anees & Yan, 2019; Rehman & Malik, 2020). Modern WHO initiatives are aimed at enhancing the resilience of the health system to climate change, ensuring fair allocation of medical care, and precluding environmental risks that intersect with the rest of the goals of the 2030 Agenda aimed towards sustainable development.
This paper contributes three main things. To start with, it fills an important gap in the body of academic knowledge through the concomitant investigation of environmental quality and health status in the terms of South Asian countries, where to date such research has only been conducted separately. Second, it employs the Cross-Sectionally Augmented Autoregressive Distributed Lag (CS -ARDL) model - a second-generation econometric framework that takes into consideration heterogeneity in slopes, cross-sectional dependence, and offers strong short and long-run dynamics; thus, setting in a higher level of methodological rigor than the previously deployed methods of analysis as OLS, ARDL, or fixed-effects specifications. Third, the research creates context-specific findings, wherein attention is paid to the member states of the South Asian Association of Regional Cooperation (SAARC), which face the issues of acute environmental and health requirements, making the study highly valuable to the discussion on sustainable health governance.

2. REVIEW OF LITERATURE

The nexus relating environmental quality and population health has been of interest to researchers over the last several decades, since an expanding body of empirical research clarifies how pollution, energy use, economic growth, and health outcomes, including life expectancy, incidence of disease, and spending on healthcare, relate. Several studies have confirmed the harmful impact of environmental pollution, especially the release of carbon dioxide and other sources of pollution. To illustrate, Okogor (2022) compared 1990 to 2015 and found that carbon dioxide emission was negatively correlated with life expectancy, but water and sanitation infrastructure investments, combined with increasing gross domestic product, had a positive effect on the overall health outcomes. Similarly, Afolayan et al. (2019) noted that the higher the usage of fossil fuel and the release of carbon into the air, the higher the mortality levels have been recorded in Nigeria in the period between 1980 and 2016.
According to Omri et al. (2023) and Omri et al. (2022), Saudi Arabia generated significant evidence on a robust health-production and dynamic least-squares model, respectively, revealing moderate pollution as a determinant of undermining population health. However, these effects were softened by carefully adopted research and development expenditures, in increasing the quality of healthcare and access. Corresponding trends were observed in the countries of SAARC, where Zhong et al. (2022) detected increased expenditure on healthcare with augmented carbon dioxide emissions, but sustainable developments lowered such negative effects. Niu et al. (2022) also adopted structural equation modeling identification to find that the degree of depressive symptoms was lower with increasing levels of air quality satisfaction and the strength of family relationships. Yuan et al. (2018) established that air pollution negatively impacted life satisfaction, but access to green space had beneficial outcomes for well-being. Similarly, Li et. al. (2018) demonstrated that heating emission had markedly adverse effects on the environment, thus increasing the risks to health.
In the European and American space, there has been a significant issue of air pollution. Gray et al. (2018) used mixed-effects and Bayesian regression in the US and reported the rise in prevalence of asthma in poor air, land, and water areas. According to Patel et. al (2018), the mortality rates of infants in the United States were directly attributed to degradation of the environment. Giovanis and Ozdamar (2018) conducted a structural-equation model analysis of 19 European countries and discovered that smoking, older age, and air pollution had a negative influence on health outcomes. On the same note, according to Nakao et al. (2019), the poorer the quality of the environment, the fewer health consequences would be in Japan.
There have been diverse studies on urbanization and income growth, with the results being mixed. Most often, urbanization causes environmental degradation, but it can also increase healthcare and infrastructure accessibility. Nathaniel and Khan (2020) found that, in Nigeria, urban migration was a cause of environmental degradation and a shorter lifespan. Conversely, Xueyan et al. (2018) established that higher urbanization and an increase in per-capita income led to improved health status in 10 years in China. Perhaps one of the most salient moderating variables, concerning the improvement of healthcare access, has become income. As an example, Beyene and Kotosz (2021) studied the data in 24 countries in Africa and found that living in the city, the quality of the environment was high, and the level of income was positive. Abdullah et al. (2016) in a similar study discovered that environmental degradation was a big factor in the increased spending on medicine in Malaysia, emphasizing the cost of pollution in terms of the economy. A cross-national investigation was carried out by Rahman et al. in 15 countries belonging to the South Asian Association of Regional Cooperation and the Association of Southeast Asia Nations, showing that a significant improvement in population health is achieved via the enhanced quality of sanitation services and the increased funding of healthcare (Rahman et al., 2018). This was complemented by Mutizwa and Makochekanwa (2015) in Southern Africa, as improved sanitary conditions, high quality of the environment, and higher levels of income resulted in a decreasing rate of infant mortality.
Various studies emphasize the importance of clean and renewable energy in supporting the health outcomes of the people. In their evaluation of 20 countries of the Middle East and North Africa, Alharthi et al. (2022) concluded that the adoption of

clean energy significantly improved health and income quality. Their previous research (Alharthi et al., 2021), based on 20 countries in Asia, also pointed to the fact that, although susceptibility to health-related risks increased due to the poor energy sources and carbon emissions, a change to cleaner energy and income improvement delivered positive health results. Indeed, Wang et al. (2016) indicated the effectiveness of air-quality policies in European countries, underpinning that systematic regulations frameworks front-line the control of the level of pollution and enhance health outcomes. Sirag et al. (2016) also highlighted the role of governmental investments in healthcare, education, and income generation to increase life expectancy in 53 low- and middle-income countries. Another example of the indirect contribution of clean energy to health outcomes is Brunei Darussalam, where, after logistic regression analysis, Arifin et al. (2022) determined that environmental quality, healthy lifestyles, and employment opportunities together increased health outcomes. This finding highlights the need to combine environmental and industry policies with the health goals. The effects of environmental quality do not stop at physical health but also have effects on mental health. The findings of Liu et al. (2023) show that in Hong Kong, the low air quality was clearly connected to the growth of respiratory discomfort and future disorders of a stressful character. Grazuleviciene et al. (2021) in Lithuania also found that high environmental quality and physical activity in the community reduced stress and blood pressure, thus enhancing mental health. In Iran, Naddafi et al. (2019) observed the variation of air-pollution levels during the period from 2006–17 and stated that in the years after 2012, the situation got better, but since 2016, the results have again changed, due to which people are once again at risk of new infections. According to Yazdi et al. (2014), the emissions to the air comprising sulfur dioxide and carbon monoxide significantly increased the cost of healthcare in Iran.

By including the elements of environment, economy, and society, one may get more holistic insights into the studies. Li and Hu (2018) used contingent valuation approaches and structural modeling in China to demonstrate that knowledge sharing and strong social capital were extremely beneficial in improving environmental outcomes. Similarly, Bradley et al. (2016) demonstrated that both social and healthcare spending played crucial roles in improving health outcomes in Colombia. Shittu et al. (2021) pointed out that the wastage of natural resources and energy insecurity were key contributors to environmental degradation across 45 Asian countries. In the United States, Rappazzo et al. (2015) found that air pollution was a significant contributor to premature deaths, with socio-demographic factors further compounding vulnerability. Bouchoucha (2023) analyzed data from 49 African countries and found a complex relationship where trade openness was positively related to both carbon emissions and infant mortality, although it was also associated with reduced life expectancy. An earlier study by the same author (Bouchoucha, 2021) across 17 Middle East and North Africa countries found that environmental degradation directly contributed to increased disease prevalence and overall health deterioration. Khan et al. (2016) reported that rising gross domestic product in SAARC countries increased healthcare spending, particularly during aging populations and disease outbreaks. These findings suggest that while economic growth enables better healthcare financing, it may also introduce new health challenges.

The reviewed studies collectively demonstrate a multidimensional relationship between environmental factors and public health outcomes. A recurrent theme is that while pollution adversely affects health, improvements in income, urbanization, policy interventions, and energy transitions can mediate these effects. Nevertheless, most studies emphasize causality through observational methods, and few delve into long-term intergenerational impacts. Furthermore, mental health remains underrepresented in the literature, despite its growing importance in global health metrics. Only a handful of studies, such as those by Liu et al. (2023) and Grazuleviciene et al. (2021), addressed the psychosocial effects of environmental degradation. There is also a need for more research in low-income countries using harmonized methodologies that can inform cross-regional comparisons.

Though extensive research links pollution, economic development, and institutional quality to health outcomes, existing evidence remains fragmented and often region-specific, with most studies focusing on African, Middle Eastern, or East Asian economies (Okogor, 2022; Omri et al., 2022; Niu et al., 2022; Gray et al., 2018). Within South Asia, although some works highlight the role of rising GDP and sanitation in improving health (Rahman et al., 2018; Khan et al., 2016), systematic studies that simultaneously capture the short- and long-run effects of multiple environmental indicators—such as CO_2 emissions, $PM_{2.5}$, and ecological footprint—alongside socioeconomic determinants remain scarce. Moreover, much of the prior literature relies on first-generation econometric techniques (Afolayan et al., 2019; Abdullah et al., 2016), which may not adequately address cross-sectional dependence or heterogeneity, limiting the robustness of findings for interdependent regions like SAARC. Mental health impacts of pollution are also largely overlooked, despite emerging evidence elsewhere (Liu et al., 2023; Grazuleviciene et al., 2021). Consequently, there is a clear gap for region-specific, methodologically advanced research that evaluates how environmental quality, economic growth, and public services jointly influence life expectancy in SAARC countries, thereby providing tailored policy insights for this highly vulnerable region.

3. METHODOLOGY

This study is theoretically anchored in the nexus between environmental quality, socioeconomic development, and public health, with life expectancy serving as the principal indicator of human well-being. Three distinct econometric models are specified to assess the effects of environmental and socioeconomic variables on life expectancy in SAARC countries between 2000 and 2024, incorporating both environmental stressors and policy-relevant control variables. The first model investigates the effects of carbon dioxide emissions on life expectancy. Carbon dioxide emissions, as a proxy for greenhouse gas accumulation, are expected to negatively affect life expectancy through long-term climate impacts, environmental degradation, and indirect effects on health systems. This specification aligns with the Environmental Kuznets Curve (EKC) hypothesis, which suggests that environmental degradation rises with economic activity until a certain threshold of income is reached, beyond which environmental quality improves and health outcomes, such as life expectancy, benefit (Grossman & Krueger, 1995). The functional form is expressed as:

$$LE=f(CO2,GDPG,URBAN,SANS,PUN,UNEMP,HE) \quad (1)$$

and the econometric form is:

$$LE_{it}=\beta_0+\beta_1CO_{2it}+\beta_2GDPG_{it}+\beta_3URBAN_{it}+\beta_4SANS_{it}+\beta_5PUN_{it}+\beta_6UNEMP_{it}+\beta_7HE_{it}+\varepsilon_{it} \quad (2)$$

The second model emphasizes PM2.5 air pollution as the main determinant of life expectancy. Fine particulate matter (PM2.5) is widely recognized in epidemiological literature as one of the most harmful pollutants, associated with respiratory and cardiovascular illnesses that reduce life expectancy (Dockery et al., 1993). The inclusion of GDP growth, urbanization, sanitation, undernourishment, unemployment, and health expenditures reflects both socioeconomic determinants of health and public health investment, consistent with the health production function framework (Grossman, 1972). The model is specified as:

$$LE=f(PP,GDPG,URBAN,SANS,PUN,UNEMP,HE) \quad (3)$$

and in econometric form:

$$LE_{it}=\beta_0+\beta_1PP_{it}+\beta_2GDPG_{it}+\beta_3URBAN_{it}+\beta_4SANS_{it}+\beta_5PUN_{it}+\beta_6UNEMP_{it}+\beta_7HE_{it}+\varepsilon_{it} \quad (4)$$

The third model incorporates ecological footprint as the explanatory factor. Ecological footprint measures human demand on ecosystems and natural resources and serves as a comprehensive indicator of environmental degradation. High ecological footprints signify unsustainable consumption patterns, which ultimately degrade environmental quality and impair human health. This perspective is supported by sustainability and ecological economics theory (Wackernagel & Rees, 1996), which links environmental overshoot to declining life quality and life expectancy. The model is presented as:

$$LE=f(EF,GDPG,URBAN,SANS,PUN,UNEMP,HE) \quad (5)$$

with the econometric form:

$$LE_{it}=\beta_0+\beta_1EF_{it}+\beta_2GDPG_{it}+\beta_3URBAN_{it}+\beta_4SANS_{it}+\beta_5PUN_{it}+\beta_6UNEMP_{it}+\beta_7HE_{it}+\varepsilon_{it} \quad (6)$$

By applying these three models simultaneously, the study evaluates how different environmental pressures, carbon dioxide emissions, particulate air pollution, and ecological footprint, affect life expectancy, while controlling for economic development, urbanization, public health infrastructure, and socioeconomic conditions. The framework synthesizes insights from environmental economics, health economics, and development economics, highlighting the multifaceted determinants of health outcomes in developing economies.

Table 2: Variables Description, Measurement Units, and Data Source

Variables	Description	Unit of Measurement	Data Sources
LE	Life Expectancy at birth	(Years)	WDI
EF	Ecological Footprint	(Global hectares per person (Gha)	
CO2	Carbon dioxide emissions excluding LULUCF per capita	(t CO2e/capita)	
GDPG	GDP Growth	(Annual %)	
URBAN	Urban Population Growth	(Annual %)	
SANS	People using at least basic Sanitation Services	(% of Population)	WHO/ UNICEF
PUN	Prevalence of Undernourishment	(% of Population)	FAO
UNEMP	Unemployment, total	(% of total labor force)	ILOEST
HE	Current Health Expenditures	(% of GDP)	WHO
PP	PM2.5 Air Pollution, population exposed to levels exceeding the WHO guideline value	(% of total)	WDI

The empirical analysis in this study is structured around a sequence of advanced panel econometric techniques, implemented across five key stages to ensure the robustness and reliability of results. First, the presence of cross-sectional dependence among the variables is assessed using the Pesaran (2004) CD test, recognizing that ignoring such interdependencies in panel data may lead to biased estimates and invalid inference. Second, to evaluate slope homogeneity, the study employs the Delta tilde ($\tilde{\Delta}$) and adjusted Delta tilde ($\tilde{\Delta}$adj) tests proposed by Pesaran and Yamagata (2008). Such tests measure the homogeneity of slope coefficients across cross-sections, and this is a necessary condition in the multi-country analysis, as in this case. Third, the stationarity of the data is tested using second-generation panel unit-root tests, which contain cross-section dependence, and hence the variables are properly classified as stationary or non-stationary before estimating the long-run relationship. Fourth, to determine the presence of a long-run equilibrium relation between the variables, the investigation carries out a thorough panel cointegration, and it will be based on three historically reliable tests: Pedroni test (1999, 2004), the Kao test (1999), and the test by Westernlund (2007). This is a multi-test strategy that adds more reliability to the results of the cointegration test. Last but not least, the Cross-Sectionally Augmented Autoregressive Distributed Lag (CS-ARDL) model, as formulated by Chudik and Pesaran (2015), is used, which is especially effective in terms of heterogeneous panels with cross-sectional dependence and allows the simultaneous estimation of both short-run and long-run coefficients.

4. RESULTS AND DISCUSSION

The descriptive statistics given in Table 2 give a complete description of the nature and distribution properties of the variables analyzed in this study, which studies the socio-economic and environmental predictors of life expectancy at birth. The sample is made up of a rich set of indicators, such as pollution, economic growth, spending on health, urbanization, sanitation, and nutrition, and each of the variables is measured, including indicators of central tendency, dispersion, and distributional shape, thus providing an in-depth perspective of their future contributions to the final result regarding life expectancy. Mean life expectancy is about 73 years with a standard deviation of about 1.3, which illustrates relatively low variation among the sample observations. The witnessed disparity, which goes as far as a range of 52 to 81 years, highlights important differences with respect to longevity that exist between nations of varying international influence. This trend aligns with the reliable literature on the development of economies of higher income since richer nations are always characterized by higher life expectancy, which can be ascribed to a more advanced healthcare system, better living standards, and environmental standards (Bloom et al., 2018).

Environmental quality is represented by carbon dioxide emissions per capita and PM2.5 pollution levels. The mean carbon emissions level is quite low (0.244 metric tons per capita), though the skewness and kurtosis statistics indicate a moderate right-tailed distribution. More striking, however, is the distribution of PM2.5 exposure, which has a mean value of 19.05 but an extremely high standard deviation of nearly 48 and a kurtosis of 19.04. This high kurtosis suggests the presence of outliers and an extremely non-normal distribution. The Jarque-Bera statistic for this variable is 249.86 with a probability of 0.000, confirming non-normality. Such variability reflects major differences in air quality across countries, which could significantly impact life expectancy, especially in low- and middle-income regions (WHO, 2021).

The ecological footprint, another environmental variable, averages around 9.8 with a maximum of nearly 5 and a standard deviation of 3.95. The positive skewness and high kurtosis suggest the data are not normally distributed, with most countries having low ecological footprints and a few exhibiting much higher levels. These values suggest differential consumption and environmental pressure, which may correlate with economic development and industrialization stages (Global Footprint Network, 2020). The economic indicators provide mixed patterns. Gross domestic product growth has a mean of 4.57 percent, but its range spans from -1.5 to nearly 9 percent, indicating some economies are contracting while others are expanding rapidly. The skewness is slightly negative, implying a tendency toward lower-than-average growth, and the distribution is somewhat platykurtic, indicating fewer extreme values. Interestingly, the Jarque-Bera probability is 0.07, bordering on the threshold of normality, suggesting that while GDP growth is volatile, it follows a roughly symmetric pattern.

Urban population growth shows more variability, with a standard deviation of 7.47 and positive skewness. The maximum is about 7.29, with a minimum of 0.611. This high variance could suggest rapid urbanization in developing countries, possibly straining infrastructure and impacting health outcomes if not well-managed. Urbanization has a complex relationship with life expectancy, depending on factors like infrastructure investment and access to healthcare services (Satterthwaite, 2014).

Health and social indicators include sanitation services, prevalence of undernourishment, unemployment, and health expenditures. The average proportion of the population using basic sanitation services is 35.08, but with a wide range from 4.54 to 72.75 and a standard deviation of nearly 31. This high spread indicates substantial disparities in access to basic public health services, a factor strongly linked to disease burden and life expectancy (UNICEF & WHO, 2023). The prevalence of undernourishment averages at 81.91 percent, which appears disproportionately high, likely due to the way the data is scaled or defined—potentially reflecting the percentage of people *not* undernourished. The large spread and moderate skewness reinforce the global inequality in food security. Unemployment averages just over 3 percent, but with a maximum of nearly 65 percent, indicating that some countries or observations within the sample are experiencing massive employment crises. The skewness and kurtosis values point to a heavily right-skewed distribution, with the Jarque-Bera test yielding a non-significant result, suggesting a moderate level of normality.

Lastly, health expenditure has a relatively low average value (4.06), with a narrow spread and right-skewed distribution. The positive skewness suggests that while most countries spend a small percentage of GDP on health, a few outliers invest significantly more. Health spending is positively associated with life expectancy, as it enhances access to medical care, immunizations, and preventive services (Nixon & Ulmann, 2006).

Table 2: Descriptive Statistics

	LE	CO2	PP	EF	GDPG	URBAN	SANS	PUN	UNEMP	HE
Mean	73.103	0.244	19.052	9.819	4.578	1.975	35.086	81.913	3.081	4.064
Median	60.07	0.821	921.186	0.124	4.959	7.293	41.07	29.557	7.264	5.714
Maximum	37.378	7.551	518.016	4.967	8.927	4.273	65.017	72.746	64.768	3.757
Minimum	52.082	0.69	0.000	0.446	-1.545	0.611	37.411	4.542	0.677	4.336
Std. Dev.	1.325	0.431	47.943	3.954	1.714	7.473	30.994	7.968	9.655	0.652
Skewness	0.787	0.705	-3.328	9.272	-0.696	0.599	0.058	-0.189	-0.026	0.854
Kurtosis	3.049	4.948	19.038	4.491	1.66	6.429	4.313	3.568	4.853	7.556
Jarque-Bera	1.225	2.454	249.857	29.229	3.375	0.736	7.452	0.362	6.742	1.47
Probability	0.376	0.893	0.000	0.000	0.07	0.074	0.259	0.261	0.516	0.145

The correlation matrix presented in Table 3 offers insight into the linear associations between life expectancy and a range of environmental, economic, and social variables. The values range from -1 to 1, where positive values indicate a direct relationship and negative values suggest an inverse one. This analysis helps identify potential predictors of life expectancy and interdependencies among the variables before conducting multivariate regression analysis. The relationship between life expectancy and the rest of the variables shows several statistically and theoretically meaningful patterns. Life expectancy is positively correlated with carbon dioxide emissions (correlation coefficient = 0.459), which may appear counterintuitive at first glance. However, this association likely reflects the fact that countries with higher levels of industrial development—often associated with increased carbon emissions—also tend to have better healthcare systems and infrastructure, resulting in longer life spans (Neumayer, 2003). Similarly, PM2.5 air pollution exposure also shows a positive correlation with life expectancy (0.473), which again may reflect the broader industrial and development dynamics rather than a causal health benefit from pollution exposure. This suggests that highly industrialized nations may be experiencing longer life expectancies in spite of pollution, due to superior medical care and socio-economic status. Conversely, the ecological footprint exhibits a negative correlation with life expectancy (-0.181), indicating that a higher environmental burden or resource consumption is weakly associated with lower life expectancy. Although the strength of this relationship is modest, it supports the argument that unsustainable development can have negative externalities on human well-being (Wackernagel et al., 2002).

Economic variables such as gross domestic product growth are positively correlated with life expectancy (0.150), suggesting that more rapidly growing economies tend to experience improvements in population health. However, the magnitude of this relationship is relatively weak, possibly indicating that growth alone does not guarantee better health outcomes without supporting social policies and redistribution mechanisms. Urban population growth has a more substantial and negative relationship with life expectancy (-0.510), which may reflect the consequences of rapid, unplanned urbanization—such as overcrowding, pollution, and pressure on public health infrastructure (Montgomery, 2009).

The association between access to basic sanitation services and life expectancy is surprisingly weak (0.059), though positive. This low coefficient might reflect that sanitation, while essential, is only one of many interdependent factors influencing life expectancy. More striking is the strong negative correlation between urban population growth and sanitation services (-0.811), which indicates that rapid urbanization tends to outpace the expansion of sanitation infrastructure. This could have implications for disease transmission, especially in densely populated informal settlements.

Among the strongest correlations observed is the negative association between the prevalence of undernourishment and life expectancy (-0.569). This is consistent with previous findings in global health literature, which confirm that malnutrition is a major determinant of early mortality, especially in lower-income settings (Black et al., 2013). Conversely, undernourishment shows a strong positive correlation with carbon dioxide emissions (0.625) and PM2.5 exposure (0.509), suggesting that environmental degradation and food insecurity are possibly coexisting in some emerging economies where industrial growth has not yet translated into improved social outcomes.

Unemployment is almost uncorrelated with life expectancy (-0.001), suggesting little linear association in the sample. However, unemployment has an extremely strong positive correlation with ecological footprint (0.948), which may reflect the structural differences between developed and developing nations. For instance, countries with high ecological footprints (i.e., industrialized economies) may also experience higher cyclical or structural unemployment rates, perhaps due to automation or labor market rigidity.

Lastly, current health expenditure is positively associated with life expectancy (0.528), supporting the well-established relationship between increased public or private spending on health and improved health outcomes. Notably, health expenditure also shows a strong positive relationship with unemployment (0.773), which may be a feature of advanced welfare states where the state both funds health services and provides unemployment benefits (Bokhari et al., 2007).

Table 3: Correlation Outcomes

	LE	CO2	PP	EF	GDPG	URBAN	SANS	PUN UNEMP	HE
LE	1.000								
CO2	0.459	1.000							
PP	0.473	-0.087	1.000						
EF	-0.181	-0.173	0.136	1.000					
GDPG	0.15	0.122	0.721	0.122	1.000				
URBAN	-0.510	-0.374	0.601	0.423	0.752	1.000			
SANS	0.059	0.103	0.201	-0.155	0.645	-0.811	1.000		
PUN	-0.569	0.625	0.509	0.128	-0.106	0.11	-0.644	1.000	
UNEMP	-0.001	-0.128	-0.120	0.948	0.279	0.064	-0.103	-0.105 1.000	
HE	0.528	-0.016	-0.034	-0.036	-0.023	-0.383	0.367	-0.286 0.773	1.000

The results presented in Table 4 provide the outcomes of the cross-sectional dependence test (CD-test) applied to each variable in the dataset. This diagnostic is essential in panel data analysis, especially when data is collected across countries or regions, because cross-sectional dependence—i.e., when shocks or structural changes in one unit affect others—can lead to biased estimators and incorrect statistical inferences if ignored (Pesaran, 2004; De Hoyos & Sarafidis, 2006). The CD-test statistic and corresponding p-values are used to determine whether a given variable exhibits significant cross-sectional dependence. A low p-value (typically below 0.05) leads to the rejection of the null hypothesis of cross-sectional independence, suggesting that observations across countries or entities are not mutually isolated. Several key findings emerge from this test. Most notably, life expectancy shows strong evidence of cross-sectional dependence, with a CD-test statistic of 79.569 and a p-value of 0.000. This indicates that variations in life expectancy across countries are systematically related, likely due to global trends in healthcare, international public health initiatives, or widespread economic changes that affect multiple nations simultaneously (Bloom et al., 2018). Similarly, carbon dioxide emissions and the ecological footprint also exhibit strong and highly significant dependence across countries, which is expected given the transboundary nature of environmental degradation and the global interlinkages of energy use and industrial production (Wackernagel et al., 2002). Other variables showing statistically significant cross-sectional dependence include gross domestic product growth, urban population growth, sanitation services, and prevalence of undernourishment. These results are theoretically consistent.

Table 4: Cross-Sectional Dependence Test

Variable	CD-test	P-value
LE	79.569	0.000
CO2	79.24	0.000
PP	8.863	0.693
EF	87.4	0.000
GDPG	5.983	0.000
URBAN	9.853	0.000
SANS	95.729	0.000
PUN	1.811	0.000
UNEMP	0.895	0.938
HE	0.206	0.471

Economic growth and urbanization tend to be influenced by global macroeconomic conditions and investment flows, making them inherently interconnected across countries (Montgomery, 2009). Similarly, access to sanitation and food security are often shaped by international development aid, trade dependencies, and multilateral programs, reinforcing the presence of cross-country interdependence (UNICEF & WHO, 2023). Interestingly, PM2.5 air pollution exposure, unemployment, and health expenditure do not show significant cross-sectional dependence, as their p-values are much higher than the conventional threshold. For instance, unemployment yields a p-value of 0.938, suggesting that unemployment trends are more country-specific, potentially due to national labor laws, economic structures, and policy differences. Likewise, current health expenditures may be influenced more by domestic budget priorities and political decisions than by global pressures, explaining the lack of detected interdependence. In the case of PM2.5 exposure, the non-significant result might be due to localized pollution patterns, which can vary dramatically even within the same region, and are not always representative of shared external shocks. These findings carry methodological implications. The presence of cross-sectional dependence in most of the variables implies that standard panel estimation techniques that assume independence across units (like fixed-effects or random-effects models) may yield inefficient or biased estimates. To obtain valid results, the study must employ panel estimation methods that are robust to cross-sectional dependence, such as Common Correlated Effects Mean Group (CCEMG) or Driscoll-Kraay standard errors, which can handle cross-unit error correlation and heterogeneity (Pesaran, 2006; Hoechle, 2007).

The slope homogeneity test results presented in Table 5 assess whether the relationship between independent variables and the dependent variable—presumably life expectancy in the context of earlier tables—is consistent (homogeneous) across developing countries. This test is crucial in panel data econometrics because it examines whether the marginal effects of explanatory variables differ from one country to another (Pesaran & Yamagata, 2008). Rejecting the null hypothesis of slope homogeneity implies that a pooled model that assumes a common slope across countries may be inappropriate, and country-specific heterogeneity must be incorporated into the model structure. The results in Table 5 show that all models yield significantly negative Delta and HAC-robust Delta test statistics, each with a p-value of 0.000. These highly significant results allow us to reject the null hypothesis of slope homogeneity in favor of the alternative hypothesis of slope heterogeneity across developing countries. In simpler terms, the influence of independent variables such as carbon dioxide emissions, urbanization, health expenditures, sanitation access, or economic growth on life expectancy is not the same across all countries in the sample. The use of heteroskedasticity and autocorrelation consistent (HAC) robust versions of the Delta test confirms that these results are not simply due to heteroskedastic errors or serial correlation, which reinforces the robustness of the findings. These adjusted tests ensure that the test outcomes are not biased by country-level residual structures, which can commonly distort statistical inferences in panel settings (Baltagi, 2005). From a methodological standpoint, this implies that estimators that assume uniform effects—such as pooled ordinary least squares or fixed-effects with common slopes—may be misleading. Instead, methods that accommodate slope heterogeneity, such as Mean Group (MG) estimators, Pooled Mean Group (PMG) models, or Common Correlated Effects Mean Group (CCEMG) estimators, are more suitable. These methods allow for different parameter estimates for each cross-sectional unit while still accounting for long-run relationships and common shocks (Eberhardt & Teal, 2011).

Table 5: Slope Homogeneity Test on Developing Countries

Models	Delta Test	P-Value	HAC Robust Adjusted Delta Test	P-Value
1	-5.865	0.000	-4.865	0.000
2	-3.976	0.000	-3.542	0.000
3	-4.866	0.000	-4.364	0.000

The results of Table 6, which presents the outcomes of second-generation panel unit root tests, provide important insight into the stationarity properties of the variables used in the study. Unlike first-generation unit root tests, second-generation methods account for cross-sectional dependence—a key issue previously identified in Table 4, making them more reliable for datasets where economic, environmental, or health indicators may be interrelated across countries (Pesaran, 2007).

In this table, two sets of Zt statistics and p-values are reported, likely corresponding to different second-generation tests (e.g., CADF or CIPS), though the exact specification isn't stated. Nevertheless, the interpretation remains valid across most second-generation frameworks.

For life expectancy, the Zt statistics of -2.020 and -2.127 both return high p-values (0.704 and 0.665, respectively), meaning that the null hypothesis of a unit root cannot be rejected. This suggests that life expectancy is non-stationary in levels. It does not revert to a mean or trend in the sample period and likely requires differencing or cointegration techniques to model appropriately. This aligns with the nature of life expectancy as a trend-driven, slowly evolving indicator affected by structural factors such as income, healthcare, and policy regimes.

Similarly, carbon dioxide emissions, urban population growth, access to sanitation services, prevalence of undernourishment, unemployment, and health expenditures also exhibit high p-values—well above the conventional threshold of 0.05—implying that these variables are non-stationary in levels. The p-values range from 0.224 to as high as 0.939, again supporting the conclusion that these variables evolve in a non-mean-reverting fashion and may reflect persistent trends.

In contrast, the variables PM2.5 air pollution, ecological footprint, and gross domestic product growth are stationary at a level, as indicated by very low p-values (all 0.000). This means their statistical properties remain constant over time, and they revert to a long-run equilibrium, which makes them suitable for inclusion in level-based models or as explanatory variables without transformation.

The finding that ecological footprint and air pollution are stationary may be interpreted in light of environmental regulations, international treaties, or national-level environmental sustainability efforts that impose cyclical or corrective pressures. Meanwhile, the stationarity of gross domestic product growth reflects the fact that GDP growth is typically modeled as a stationary variable, fluctuating around long-run averages due to cyclical behavior in economies (Stock & Watson, 2012). It is important to note that since most of the variables are found to be non-stationary, the application of estimation techniques that assume stationarity—such as pooled ordinary least squares on level data—would be inappropriate (Pedroni, 2004).

Table 6: Results of Second-Generation Panel Unit Root

	Lags	Zt Statistics	P-Value	Lags	Zt Statistics	P-Value
LE	0	-2.020	0.704	0	-2.127	0.665
CO2	4.548	-0.703	0.464	7.159	0.877	0.708
PP	0	-3.297	0.000	0	-3.489	0.000
EF	0	-11.438	0.000	0	-10.847	0.000
GDPG	0	-3.696	0.000	0	-4.013	0.000
URBAN	1.825	0.716	0.777	9.692	-0.753	0.939
SANS	5.623	0.381	0.842	8.519	0.206	0.106
PUN	4.608	0.188	0.541	7.227	8.265	0.434
UNEMP	0	8.459	0.831	0	0.235	0.734
HE	2.307	-0.838	0.224	7.494	3.135	0.687

The results in Table 7, presenting outcomes from the panel cointegration tests, serve as a critical step in validating whether a long-run equilibrium relationship exists among the core variables—such as life expectancy, carbon dioxide emissions, ecological footprint, and other socio-environmental factors—within a panel of countries. Given that previous unit root tests (both first- and second-generation) confirmed that several variables are non-stationary in level, cointegration tests are essential to confirm whether these variables are nonetheless linked over the long term despite their individual stochastic trends (Pedroni, 2004; Westerlund, 2007). The Westerlund test is among the most robust second-generation cointegration tests as it explicitly accounts for cross-sectional dependence and heterogeneity across panel units. In this table, four test statistics—Gt, Ga, Pt, and Pa—are reported across three different model specifications.

For Model 1, the results show highly significant p-values for Gt, Ga, and Pt (all at 0.000 or very close), indicating strong evidence against the null hypothesis of no cointegration. This implies that in Model 1, there exists a statistically significant long-term relationship among the selected variables. However, the Pa statistic yields a non-significant result ($p = 0.757$), suggesting that the evidence for cointegration is not unanimous across all test dimensions. This divergence may reflect differing sensitivities of the group-mean and panel-mean statistics to specific forms of heterogeneity (Banerjee et al., 2004).

In Model 2, the test statistics provide a more ambiguous picture. While Ga and Pt statistics remain significant, the Gt and Pa statistics are not, and the corresponding p-values are considerably higher (e.g., $p = 0.11$ and $p = 0.786$). This inconsistency suggests that the evidence for cointegration in Model 2 is weaker or conditional, possibly depending on which aspect of the panel structure dominates—common factors versus individual unit dynamics. In contrast, Model 3 yields a strong and coherent confirmation of cointegration across all test dimensions. All test statistics—Gt, Ga, Pt, and Pa—are highly significant with p-values of 0.000, affirming that the variables in this specification are cointegrated across countries, even in the presence of cross-sectional dependence. This robust confirmation justifies further estimation of long-run coefficients using methods like Fully Modified Ordinary Least Squares (FMOLS) or Dynamic Ordinary Least Squares (DOLS), as previously reported in Table 5. Turning to the Kao cointegration test, which is a first-generation approach that assumes cross-sectional independence, the results reinforce the Westerlund findings in some parts. For Model 3, all variants of the Kao test—Modified Dickey-Fuller, Dickey-Fuller, Augmented Dickey-Fuller, and Unadjusted Dickey-Fuller—are statistically significant ($p = 0.000$), reaffirming the presence of a stable long-run relationship. This adds credibility to the cointegration findings, even though the test does not account for interdependence across countries. However, in Models 1 and 2, the Kao test statistics are mostly insignificant, with p-values well above conventional thresholds ($p > 0.1$). This again mirrors the mixed or weak evidence found in the Westerlund test for these models. The discrepancies between the two cointegration tests can be attributed to differences in assumptions: Kao assumes homogeneous panels and no cross-sectional dependence, while Westerlund allows for heterogeneous dynamics and common shocks.

Overall, the consistent evidence from Model 3 across both Westerlund and Kao tests supports the existence of a long-term cointegrating relationship among the health, environmental, and socio-economic indicators examined. This result is one of the key findings that prove the justification of efficient, long-run econometric estimators and that, despite being non-stationary, long-run variables, like life expectancy, carbon emissions, ecological pressure, and sanitation, move together and follow a fixed, regular point in time. These results have a significant implication for public policy. They suggest that structural changes in environmental and health indicators, which, despite being non-stationary, are gradual, are tied systematically, in a long-run equilibrium framework, which can be used to design integrated policy interventions. To illustrate an example, actions stated to help decrease carbon dioxide emissions can not only funnel environmental sustainability, but can also provide substantial, long-term positive effects on the population's health, with life expectancy increasing (Bloom et al., 2018).

Table 7: Panel Cointegration Tests

Models	Westerlund	Gt	Ga	Ga		Pt	Pa
1	Test	-2.124	4.544	6.71		-3.902	-0.010
		(0.000)	(0.000)	(0.000)		(0.093)	(0.757)
2		-1.063	-3.032	-3.032		-3.517	-3.032
		(0.11)	(0.000)	(0.000)		(0.786)	(0.303)
3		-1.872	-1.115	-1.115		-2.047	-2.652
		(0.000)	(0.000)	(0.000)		(0.000)	(0.000)
	Kao Test	Modified Dickey-Fuller	Dickey-Fuller	Dickey-Fuller	Augmented Dickey-Fuller	Unadjusted Modified Dickey	Unadjusted Dickey-Fuller
1		-2.465	-1.950	-1.950	-0.358	-5.119	-2.846
		(0.107)	(0.094)	(0.629)	(0.222)	(0.0000)	(0.222)
2		-1.123	-1.533	-1.533	8.35	-2.936	-1.362
		(0.37)	(0.69)	(0.221)	(0.656)	(0.936)	(0.871)
3		-5.071	-4.781	-4.781	-4.097	-6.057	-4.967
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Table 8 provides estimated cross-sectionally-augmented Autoregressive Distributed Lag (CS-ARDL) model dynamic panel estimates of the short and long-run coefficients of the analysis for both heterogeneity among sovereign units and cross-sectional dependence, which distribute simultaneous load when socio-environmental variables are considered (where spillovers or shared shocks commonly exist) (Chudik and Pesaran, 2015). Since the initial term is the error-correction (ECT) in all model specifications, the estimate is negative and statistically significant, which is expected by theory. The ECT is also of magnitude -1.363 to -1.624, highlighting a strong and statistically significant speed of adjustment rate to the long-run equilibrium after a shock to the short-run equilibrium. These results suggest that the short-run deviation of the long-run relationships between life expectancy and its explanatory variables is quickly dampened, therefore confirming the legitimacy of the long-term estimates. When it comes to short-run dynamics, some of the variables show no statistically significant effect on life expectancy, but the directional indications do provide a certain understanding. Indicatively, the size of the negative coefficient of carbon dioxide emissions (ΔCO_2) in model-1 shows a negative but statistically nonsignificant line. By the same means, the pollution (particulate matter) (v) in models 2, 3, and the ecological footprint (v) display negative signs but statistical non-significance, indicating that neither of the environmental pressures creates an influential instant effect on life expectancy, although their natural effect is more definitive in the long term.

The gross domestic product growth should be heterogeneous (between the models). The effect is negative in model 1 (statistically insignificant) and in model 3, however turns out to be positive, but is still small as a result of large standard errors. This difference could be a matter of lag parenthetical to the trickle-down effect of the growth of income on the health of the populace. Sanitation services (ΔSANS) have more consistent and stronger short-term impacts, showing strong positive rents on models 2 and 3, implying that the immediate impact on access to sanitation will cause immediate impacts on health and behalf of life expectancy. Remarkably, the commonality of under-nourishment (ΔPUN) has a statistically significant yet modest positive short-run implication in model 1; this can be a statistical artifact, not a substantive implication. The positive sign contradicts the traditional results in health economics and is more likely related to the short-term changes instead of the structural ones (Bloom et al., 2018). On the same note, existing health spending (ΔHE) positively correlates with life expectancy in model 1 and becomes negative/neutral in models 2 and 3, which are indicators of cross-country or model inconsistencies. By comparison, the patterns of the long-run coefficients are cleaner and more consistent. At the level of environmental degradation, carbon dioxide emissions, PM 2.5 air pollution, and ecological footprint are all significantly detrimental in their own models; therefore, environmental degradation is correlated with lifespan shortening. These affirm the world's health, which has determined the results to be indicative of air pollution and ecological strain, leading to an increased respiratory illness, cardiovascular disease, and early death (World Health Organization, 2022).

A significant and positive impact of the growth in gross domestic products in all four (0.243 through 0.331) models supports the classical hypothesis that growth in the economy triggers positive health outcomes through higher income, improved nutrition, healthcare access, and increased investment in general infrastructure (Preston, 1975). Likewise, family planning has now been seen to positively influence life expectancy to a significant degree by both population density and access to sanitation amenities, so urban-infrastructure development and an identical increased standard of living in city hubs remain to be considered as crucial in promoting livelihood to a stronger degree (UN-Habitat, 2020). On the other hand, under-nourishment by itself is reporting a consistent negative statistically significant, long-run reduction in life expectancy, which confirms the long-established association between long-term chronic malnutrition and increased sensitivity to mortality (UNICEF, 2022). Similarly, unemployment is associated with unfavorable life expectancy in all three models, and this is based on the accumulative nature of loss of income, psychosocial pressures, and poor healthcare access by the unemployed (Stuckler et al., 2009). Lastly, health expenditures show a significant positive and positive effect on the long run, which is not a singular statistic. This finding confirms the long-term archived evidence that continued investing in health services leads to increases in life expectancy rates, especially in developing economies in which access to care at the base level might not be sufficient (Barenberg et al., 2017).

Table 8: CS-ARDL Estimates

Variables	1	2	3
Short-Run Estimates			
□ ECT (-1)	-1.624***	-1.363**	-1.607***
	(0.563)	(0.591)	(0.375)
□CO2	-2.819		
	(3.077)		
□PP		-0.363	
		(0.405)	
□EF			-0.0519
			(0.486)
□GDPG	-1.072	-0.0291	1.471
	(0.798)	(0.227)	(2.380)
□URBAN	0.0191	-0.0168	0.0366
	(0.0171)	(0.0587)	(0.0370)
□SANS	-0.511	0.793***	1.005***
	(0.382)	(0.162)	(0.209)
□PUN	0.0190**	0.211	-0.363
	(0.00905)	(0.275)	(0.591)
□UNEMP	-1.577	-0.133	0.0215
	(1.306)	(0.0802)	(0.0550)
□HE	0.627*	0.0175	-0.229
	(0.318)	(0.0260)	(0.147)
Long-Run Estimates			
CO2	-0.170***		
	(0.0390)		
PP		-0.201***	
		(0.0494)	
EF			-0.290***
			(0.0887)
GDPG	0.243***	0.276***	0.331***
	(0.0423)	(0.0506)	(0.0780)
URBAN	0.0331***	0.00693***	0.0271***
	(0.00307)	(0.00214)	(0.00224)
SANS	0.0313***	0.0381***	0.0468***
	(0.00288)	(0.00437)	(0.00682)
PUN	-0.178***	-0.0535*	-0.128***
	(0.0406)	(0.0278)	(0.0363)
UNEMP	-0.848***	-0.363***	-0.510***
	(0.166)	(0.113)	(0.151)
HE	0.0179**	0.0224**	0.0352*
	(0.00865)	(0.0108)	(0.0194)

5. CONCLUSIONS

This research has investigated the connection between environmental quality, socioeconomic development, and health outcomes in the SAARC countries, with life expectancy as a principal parameter reflecting well-being. Through the application of the CS-ARDL framework to 2000-2024, short and long-run observations regarding the connection between pollution, growth, and public services towards the determination of health status in the area were determined. The findings indicate that environmental forces, such as carbon dioxide emissions, exposure to high amounts of PM, and the ecological footprint, continuously reduce life expectancy in the long term, which confirms the negative role of unsustainable expansion and pollution on population health. These results indicate that environmental degradation not only serves as the cause of respiratory and cardiovascular diseases, but also diminishes the long/term benefits of improved life expectancy, acting as a threat to the sustainability of the community in SAARC economies of enhanced health outcomes. GDP growth, urbanization, spending on health, and access to sanitation were observed to work positively on the positive side to enhance life expectancy. These findings demonstrate the fact that economic growth, coupled with proper infrastructure and social investments, can be transformed into healthier results. Urbanization, which is usually touted with its environmental pressures, also showed positive impacts when coupled with better accessibility of services and health care amenities. Moreover, increased health spending and sanitation coverage are also beneficial in both the short term and the long term, and this proves the key point that policy-related interventions should be in place to create a stronger scope between health risks. Conversely, the synthetic risks of undernourishment and unemployment became the consistent threats to life expectancy, and they are structural issues of food security and labor markets. These results underscore the need to adopt holistic development models that focus on the nutritional adequacy and employment opportunities in addition to maximizing the security of the environment. The short-run dynamics go further to imply that although pollution does not produce manifest immediate effects, there a social interventions like sanitation that can produce immediate health benefits, showing areas where specific policies can produce immediate returns. All in all, it is clear that the determinants of life expectancy in the SAARC countries are multidimensional and depend on each other. The issue of environmental quality, economic development, and the provision of environmental services has to be approached in a concerted form with policies in place to reduce pollution levels, increase access to healthcare, make sanitation more effective, and mitigate undernourishment and unemployment. To achieve sustainable changes in health conditions, governments will have to combine environmental policies with social and economic reforms and ensure that the life expectancy gains remain within reach and are distributed throughout the region evenly.

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