

Carbon Emissions and Infectious Disease Burden in African Heavily Indebted Poor Countries: Aggregate and Country-Specific Panel Evidence, 1990-2023

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Abstract

Emissions of carbon have recently been found to pose potential public health risks since they affect air quality, transmission of climate-sensitive diseases and the environment in which infectious disease agents thrive. Nonetheless, there is little known about the relationship between carbon emissions and infectious diseases in HIPCs. This paper investigates the aggregate and individual country effect of carbon emissions on infectious disease burden in 28 HIPCs in Africa between 1990 and 2023. Infectious diseases include adult HIV prevalence rate, incidence rate of tuberculosis per 100,000 inhabitants and incidence rate of malaria per 1,000 population at risk. The dependent variables used include carbon emissions measured in metric tons per capita while other control variables used are the percentage of urban population, GDP per capita, current health expenditure and percentage access to basic sanitation facilities. For the statistical analysis, second-generation panel procedures have been employed which include cross-sectional dependence tests and slope heterogeneity test followed by the Augmented Mean Group estimator. The findings show that carbon emissions have a positive and significant effect on all three infectious-disease indicators. In aggregate terms, 1% change in carbon emissions is associated with a 0.025% change in adult HIV prevalence rate, 0.201% in tuberculosis incidence rate and 0.049% in malaria incidence rate. The effect of carbon emissions on the above three indicators shows large heterogeneities across countries such as Senegal, Burkina Faso, Cameroon, Niger, Guinea-Bissau, Gambia and Zambia depending on disease outcomes. Thus, climate and pollution sensitive public health risks need to be incorporated in debt-sensitive development, urbanization and health system financing policies in African HIPCs. It has contributed to environmental health and development literature in that carbon emissions have not only environmental-growth consequences but also disease-burden consequences in fiscally constrained African economies.

Keywords: Carbon emissions; infectious diseases; HIV; tuberculosis; malaria; African HIPCs; Augmented Mean Group; environmental health

Highlights

Carbon emissions significantly increase HIV prevalence, tuberculosis incidence and malaria incidence in African HIPCs.

The Augmented Mean Group estimates reveal heterogeneous country-specific disease responses to carbon emissions.

Malaria shows a strong environmental sensitivity in several countries, consistent with climate-sensitive vector transmission.

Health expenditure and sanitation reduce selected disease outcomes but do not fully offset the adverse emission effect.

The results support integrating climate mitigation, air-quality control and disease prevention in public-health planning.

1. Introduction

Contagious diseases still pose a great threat to the economic development challenge faced by financially strapped economies. Tuberculosis, malaria and HIV/AIDS are among the diseases that cause high mortality rates, productivity losses and welfare loss especially in developing economies with poor health care infrastructure and limited disease surveillance capability. According to the WHO's Global Tuberculosis Report 2024, tuberculosis is a leading cause of death from an infectious disease. Also, WHO statistics show that vector-borne diseases represent more than 17% of all the infectious diseases and cause more than 700,000 deaths every year (World Health Organization [WHO], 2024a, 2024b).

Environmental factors in determining the prevalence of infectious diseases have gained significance in the public health research field in recent times. Changes in climatic factors, air pollution and environmental degradation affect the infectious diseases prevalence through several ways including respiratory problems, vector ecology changes, heat stress, floods, food insecurity, and strain in urban infrastructure (Intergovernmental Panel on Climate Change [IPCC], 2023; Romanello et al., 2024; WHO, 2023). Carbon emissions therefore serve as both an indicator of climate change and also indicators of fossil fuel usage, industry growth, traffic pollution, and general ecological degradation. In economies undergoing rapid urban growth with no concomitant investments in housing, sanitation, waste management and health infrastructure, carbon emissions can exacerbate the infectious-diseases vulnerability.

The topic of carbon emissions and infectious disease prevalence is very pertinent to the HIPCs of Africa. These economies are noted to have experienced very high debts externally, limiting the fiscal space available for health care services, environmental regulation and infrastructure development. As the World Bank (2024a) indicates, 37 countries have undergone debt relief from the HIPC and MDTI, 31 out of them being in Africa. Even though debt relief has created some fiscal space, the countries still face a lot of pressures from poverty, population growth, urbanization, climatic shocks and fragile healthcare infrastructure. Such a situation makes the HIPCs of Africa good candidates in finding out whether carbon emissions determine the prevalence of infectious diseases besides the usual reasons of poverty and health expenditure.

Several research has studied the effects of air pollution, climate variability and urbanization as factors determining the outcomes of infectious and respiratory diseases. The studies on the effect of climatic changes on health show that temperatures, rainfall and environmental change affect the transmission of malaria, respiratory infections and spread of pathogens (Ebi et al., 2021; Liu et al., 2024; WHO, 2024b). Nevertheless, the empirical literature has mainly focused on the developed economies, particular disease outcome or broad regions. Very little attention has been paid to the unique situation of African HIPCs. Also, the majority of the empirical studies utilize estimators that do not consider

cross-sectional dependence and slope heterogeneity despite that African countries experience the common shocks in the form of international fuel prices, commodity cycles, pandemics, climatic events, and debt distress.

This paper tries to fill in the gap by addressing the third goal of the underlying research that is to estimate the impact of carbon emissions on the prevalence of infectious diseases in the heavily indebted poor countries in Africa. The paper uses 28 African HIPC countries between 1990 and 2023 and HIV prevalence, TB incidence, and Malaria incidence as the disease outcomes. The paper uses the AMG estimator which is appropriate when there is the presence of cross-sectional dependence and slope heterogeneity. The results give both panel and country-specific effects of the carbon emissions on the infectious diseases enabling differentiation of policy implications at country level and disease burden. The contributions made by the paper are three-fold. First, the paper repositions carbon emissions as a public-health risk factor in the debt-strapped economies of Africa. Secondly, the paper gives disease-specific evidence for HIV, TB and Malaria instead of taking infectious diseases as a single health factor. Thirdly, the paper reveals country heterogeneity in the carbon emissions-disease relationship making it easier to design environment and health policy. The rest of the paper is organized as follows: Section 2 is a literature review and theoretical channels, Section 3 contains the data and methods, Section 4 contains the results and discussion and Section 5 is the conclusion and suggestions for future research.

2. Literature Review and Analytical Framework

2.1 Carbon emissions as an environmental health risk

Carbon dioxide emissions have been linked with fossil fuel combustion, industries, transportation, burning of biomass and energy generation. Carbon dioxide alone cannot be considered the only pollutant that directly affects human health; however, it is highly related to emission-generating processes that include particulate matter, nitrogen oxides, sulphur oxides, and many other pollutants. These pollutants may irritate human lungs, impair human immunity, and make individuals more susceptible to infections. As highlighted by WHO (2023), climate change affects human health in terms of heat, air pollution, food and water insecurity, extreme weather phenomena, and infectious disease patterns. The connection between the emissions and infectious diseases takes place through two channels. First, emission-generating environments are characterized by poor air quality that makes humans more prone to respiratory diseases and makes the state of their health worse in case of tuberculosis. Second, emissions lead to climate change that impacts temperature, precipitation, and humidity patterns associated with vector-borne diseases such as malaria. Climate-related floods and inadequate drainage can create breeding grounds for mosquitoes, whereas heat and air pollution in urban areas combined with high density make diseases more probable (IPCC, 2023; Liu et al., 2024; WHO, 2024b).

2.2 Diseases in economies constrained by fiscally

African HIPC countries are characterised by a number of problems such as the high disease burden and inability to deal with public health challenges. The prevalence of TB, malaria, and HIV is connected with the high level of poverty, the low diagnostic possibilities, low treatment and preventive measures, low health finance, malnutrition, poor housing, and lack of sanitary services. Such conditions make the prevention of diseases more difficult and increase the chances of

turning environmental shocks into health crisis. Fiscal constraints do not allow countries to invest in climatically resilient infrastructure and disease surveillance.

It is necessary to emphasise the importance of the HIPC environment since it can prevent the countries from spending money on health and environmental issues because of the debt burden. Although debt relief was conducted in such countries, there still exist a lot of development needs. Therefore, environmental degradation can increase the need for health services exactly in those cases when governments have difficulties responding to this situation. Therefore, the emission-disease connection turns into the development-finance issue as well.

2.3 Theoretical background

The study is based on two theoretical approaches: Epidemiological Transition Theory and Environmental Kuznets Curve hypothesis. Epidemiological Transition Theory is explaining the process of evolution of disease patterns and shows that infectious diseases are decreasing because of the improved conditions of sanitation, nutrition, and medical care, while chronic diseases are rising (Omran, 1971). Nevertheless, many low-income countries are facing a double burden of diseases and experiencing both infectious and non-communicable disease risks. It makes Africa HIPCs the relevant case since the process of transition can be disrupted because of the urbanisation and environmental degradation.

The idea of Environmental Kuznets Curve hypothesis is that initially environmental degradation is increasing due to the economic growth but later decreases due to the increased income levels, which allow to use clean technologies, regulations and environmental preferences (Grossman & Krueger, 1995; Stern, 2004). In Africa HIPCs, the threshold of income levels required for reducing emissions can be not reached yet, and fiscal constraints do not allow countries to adopt clean technologies. It means that carbon emissions can have a negative impact on the health of local population without appropriate policies aimed at improvement of the environmental condition.

2.4 Empirical evidence and research gap

There are many empirical studies that show the impact of the environment on the outcomes of infectious diseases. For example, Liu et al. (2024) found that temperature and precipitation have the statistically significant influence on the prevalence of malaria in 57 countries and territories and the African countries are especially sensitive to the precipitation effect. Nguyen et al. (2024) found that the short-term exposure to air pollution increases the likelihood of respiratory hospital admissions among children in Hanoi. Moreover, Romanello et al. (2024) showed that the impact of climate change is evident already now and includes heat, air pollution, food insecurity, and infectious disease risks. However, there are still some gaps in the literature. First, many researchers take into account only climate variables, but not carbon emissions as the main factor. Second, country-specific heterogeneity in many cases is not considered, although the difference in disease ecology, health systems, and urban conditions in different countries is high. Third, there are few studies that consider the HIPC context, although it is characterised by specific fiscal and development vulnerabilities. It is the reason why the present study fills the existing gap in literature by estimating the aggregate and country-specific impact of carbon emissions on the prevalence of HIV, tuberculosis, and malaria in 28 African HIPCs.

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3. Data and Methodology

3.1 Data, sample and variables

The study uses panel data annually for 28 African HIPC countries for the period of 1990-2023. The list of countries includes Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Comoros, Republic of Congo, Democratic Republic of Congo, Ethiopia, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Niger, Rwanda, São Tomé and Príncipe, Sierra Leone, Senegal, Tanzania, Togo, Uganda and Zambia. The period covers the significant changes in urbanisation, disease control programs, debt relief programs, climate and environmental factors.

The dependent variables are HIV prevalence among adults aged 15-49 (PHIV), tuberculosis incidence per 100 thousand people (IOT), and malaria incidence per 1 thousand people at risk (IOM). The explanatory variable is carbon emissions per capita (CE). The control variables include urban population share (URB), GDP per capita (GDPPC), current health expenditures share (HEX), and people who have access to at least basic sanitation services share (SAN). The variables are taken from the World Development Indicators and related data from the World Bank according to the data structure of the underlying study.

Table 1. Variables and measurement

Variable	Definition	Role	Source
PHIV	HIV prevalence, total (% of population ages 15-49)	Dependent variable	World Development Indicators
IOT	Tuberculosis incidence (per 100,000 people)	Dependent variable	World Development Indicators
IOM	Malaria incidence (per 1,000 population at risk)	Dependent variable	World Development Indicators
CE	CO2 emissions (metric tons per capita)	Main explanatory variable	World Development Indicators
URB	Urban population (% of total population)	Control variable	World Development Indicators
GDPPC	GDP per capita	Control variable	World Development Indicators
HEX	Current health expenditure (% of GDP)	Control variable	World Development Indicators
SAN	People using at least basic sanitation services (% of population)	Control variable	World Development Indicators

3.2 Model specification

The baseline empirical model is specified separately for each infectious-disease outcome. The general form is:

$$ID_{it} = \alpha_i + \beta_1 CE_{it} + \beta_2 URB_{it} + \beta_3 GDPPC_{it} + \beta_4 HEX_{it} + \beta_5 SAN_{it} + \varepsilon_{it}$$

where ID_{it} represents each infectious-disease outcome for country i in year t . CE_{it} denotes carbon emissions, URB_{it} captures the level of urbanisation, $GDPPC_{it}$ represents economic development, HEX_{it} captures the public-health financing environment, SAN_{it} measures basic sanitation access, α_i captures country-specific effects and ε_{it} is the error term. The coefficient of interest is β_1 , which measures the effect of carbon emissions on infectious disease burden. A positive and significant β_1 implies that higher emissions are associated with higher disease prevalence or incidence.

The analysis is conducted for HIV, tuberculosis and malaria because the transmission mechanisms differ. Tuberculosis is closely linked to respiratory vulnerability, crowding and health-system access; malaria is climate- and vector-sensitive; HIV is primarily driven by behavioural, socioeconomic and health-system factors but may still respond indirectly to environmental stress through migration, poverty, urban concentration and health-service disruption.

3.3 Estimation strategy

Second generation panel techniques are applied since African data spanning multiple countries are subject to common shocks and heterogeneous responses. The existence of cross-sectional dependence means that shocks to one country can be correlated with shocks to another country. Shocks to countries can occur due to the global economic recession, pandemics, commodity prices changes, climate changes, international aid, debt relief cycles and environmental factors in the region. The existence of slope heterogeneity means that the effect of carbon emissions can be different across countries because of differences in disease ecology, urbanization, public health capacity and environmental regulations.

In order to address these problems, the Augmented Mean Group estimator is applied. AMG estimator accounts for the existence of country specific coefficients and the unobserved common factors via the common dynamic process (Bond & Eberhardt, 2009; Eberhardt & Teal, 2010). Thus, AMG is suitable for estimating both aggregate and country-specific effects of carbon emissions. Compared with conventional fixed effects estimator, AMG is preferred where the assumption about the existence of the same slope coefficients is not true.

4. Results

4.1 Aggregate effect of carbon emissions on infectious diseases

According to the aggregate AMG estimates, the effect of carbon emissions on all three infectious-disease indicators is positive and significant. According to Table 2, 1 percent increase in carbon emissions leads to 0.025 percent increase in HIV prevalence, 0.201 percent increase in tuberculosis incidence and 0.049 percent increase in malaria incidence. The results are significant according to the conventional criteria. Therefore, carbon emissions can be regarded as a factor which leads to higher infectious diseases burden in Africa.

The coefficient differs across diseases. The coefficient is the largest for tuberculosis. It means that tuberculosis may be more responsive to environmental and air quality conditions according to the aggregate model. It is possible due to the fact that high emission intensive environment leads to poor air quality, breathing problems, various types of pollution and crowded urban areas. Malaria is also positively influenced by emissions since carbon emissions lead to climate changes which in turn influence mosquitoes ecology and rainfall patterns. The positive coefficient of HIV infection may be explained by indirect channels.

Table 2. Aggregate AMG estimates for infectious-disease outcomes

Variable	HIV prevalence	Tuberculosis incidence	Malaria incidence
Carbon emissions (CE)	0.025***	0.201**	0.049***
Urban population (URB)	0.668**	0.552***	1.387***
GDP per capita (GDPPC)	-0.080	-0.116	-0.129***
Health expenditure (HEX)	-0.745***	-0.026**	-0.381**
Basic sanitation (SAN)	-0.660	-0.317***	-0.246

Note: Values are elasticities or semi-elasticities from the panel estimates. ***, ** and * denote significance at 1%, 5% and 10%, respectively.

The control variables exhibit the expected behaviour. Urbanisation is positively related and significant in all three dependent variables, which confirms that rapid urbanisation can enhance disease transmission because of overcrowdedness, poor quality of housing, lack of sanitation and pressures on health care services. Health expenditure reduces all the diseases, but the strength varies depending on disease types. Sanitation is negative in relation to all the outcomes, but the strongest significant impact is shown in the case of tuberculosis since it reflects the influence of better conditions of life on lowering disease vulnerability. GDP per capita is negatively related, and the strongest significant relation is seen in malaria.

4.2 Country-specific carbon-emission effects

The results from the AMG estimations of carbon-emission effects on diseases indicate the existence of heterogeneity in impacts of carbon emissions on diseases between countries. Carbon emission does not affect all countries with the same intensity and also varies according to the type of disease, which implies that there might be a risk of overlooking certain aspects of each country when implementing a common policy in the region.

For HIV prevalence, the countries with the largest carbon-emission coefficients are Senegal, Burkina Faso, Chad, Mozambique and Niger. For the incidence of tuberculosis, the top five countries with the largest coefficients are Niger, Malawi, Zambia, Liberia and Uganda. For malaria incidence, the top five countries are Guinea-Bissau, Gambia, Senegal, Cameroon and Comoros.

Table 3. Highest country-specific carbon-emission effects on HIV prevalence

Country	CE coefficient	p-value	Rank
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Senegal	1.324	0.000	1st
Burkina Faso	0.677	0.146	2nd
Chad	0.561	0.042	3rd
Mozambique	0.521	0.000	4th
Niger	0.495	0.000	5th

Table 4. Highest country-specific carbon-emission effects on Tuberculosis incidence

Country	CE coefficient	p-value	Rank
Niger	0.635	0.000	1st
Malawi	0.535	0.000	2nd
Zambia	0.432	0.000	3rd
Liberia	0.236	0.000	4th
Uganda	0.165	0.000	5th

Table 5. Highest country-specific carbon-emission effects on Malaria incidence

Country	CE coefficient	p-value	Rank
Guinea-Bissau	1.793	0.052	1st
Gambia	1.184	0.005	2nd
Senegal	1.066	0.004	3rd
Cameroon	1.022	0.000	4th
Comoros	0.753	0.141	5th

Given Senegal's high coefficient for HIV and malaria, it is evident that it has high environmental sensitivity that might be due to the high levels of urbanization, coastal exposure, movement, and strain on the health systems. It is worth noting that Niger has a high coefficient for tuberculosis and it means that emission-related environmental strain could act alongside poor housing, poverty, and inadequate health system.

Low or insignificant coefficients in some countries should not be taken as an indication that emissions are safe to human health. Instead, this might mean that there are variations in disease reports, environmental conditions, responses to health problems, policy and health system capacity and exposure of the population. Therefore, when doing studies on health panel, country-specific estimates should be taken as policy messages.

5. Discussion

5.1 Interpretation of the aggregate findings

It is true that the positive relationship between carbon emissions and infectious diseases has been established and it confirms the environmental determinants of health hypothesis. In African HIPC's, emissions are related to the processes of development that increase exposure to the risk of infectious diseases such as dependence on fossil fuels,

urban traffic congestion, industrial operations, burning of the biomass, deforestation and poor environmental regulation.

Regarding the results of tuberculosis, it is notable that this disease depends on crowding, poor ventilation, poverty, vulnerability of the immunity system and health system efficiency. Emission-intense environment could cause respiratory stress and increase health conditions that are related to TB susceptibility. Even though carbon emissions cannot be taken as direct cause of TB infection, estimates show that emissions could be a factor of the environment and socioeconomic conditions that increase disease burden.

In terms of malaria, the results show that there is a positive coefficient, which is consistent with the idea that environmental degradation and climate changes impact the transmission of vector-borne diseases. Malaria depends on temperature, precipitation, humidity, standing water and land use patterns. Poor drainage and waste management in the fast growing urban settlements could lead to creation of breeding grounds for mosquitoes. This explains the fact that malaria is heavily impacted in the countries, where carbon emission impacts interact with poor infrastructure and climate sensitivity.

Finally, the estimate for HIV should be understood through indirect channels. Emissions cannot have the same biological impact on HIV infection like malaria and other respiratory diseases. Nevertheless, environmental factors associated with the growth of emissions could change economic and social conditions. Urbanization, migrations, informal settlements, economic instability and pressure on the health system could impact prevention, treatment and risk. Therefore, positive coefficient of HIV indicates that the association of emissions is related to broader environmental and developmental stress.

5.2 Why country heterogeneity matters

Country-specific estimates indicate that the aggregate results mask significant heterogeneity, which has serious policy implications. For instance, the country with high carbon emission sensitivity to malaria will need the integrated program for vector control, investment in drainage, climate monitoring and the transition to cleaner energy. If the country has high tuberculosis sensitivity, it will need a housing policy, which is sensitive to ventilation, programs for clean cooking, emission controls in industries and improved TB screening in crowded urban areas. High sensitivity to HIV needs to incorporate the environmental shocks and urban vulnerability into the programs for prevention, adherence and treatment.

Heterogeneity in the results of the study also reflects differences in the quality of data and disease surveillance. There are countries, where disease surveillance is better and the coefficient of the association will be stronger and vice versa. It emphasizes the necessity of improvement of the environmental and health data system in African HIPC. Epidemiology should combine information about the air quality, climate, urban settlements and vulnerability at the household level.

5.3 Policy implications

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First of all, reduction of carbon emissions should be seen as a public-health measure. African HIPC's need climate and energy policies that take into consideration the health co-benefits. The investments in cleaner energy sources, transport, renewable energy, industrial emission standards and urban greening will reduce environmental health risks and support climate targets.

Second, the disease control programs need to be climate- and pollution-aware. Programs against malaria should include climate information, rainfall forecasts, drainage management and vector surveillance at the settlement level. The tuberculosis programs should include indoor air quality, housing ventilation and exposure to the crowded urban environment. Programs against HIV should be aware of economic shocks, migrations and urban vulnerability.

Third, the framework of debt relief and development financing should integrate environmental health. Since HIPC's suffer from limited fiscal space, international funding should support climate resilient health infrastructure, disease surveillance, clean energy and sanitation. This is important because the costs of health due to emissions will undermine productivity and development.

Fourth, urban planning should be a tool for prevention of diseases. Fast urbanization without proper housing, sanitation, drainage and access to healthcare will turn environmental stress into vulnerability to the infectious diseases. Therefore, urban plans should include air quality management, waste system, clean water, green space and drainage infrastructure.

6. Conclusion

In this study, the effect of carbon emissions on infectious diseases in 28 African HIPC's in the period from 1990 to 2023 was estimated. Using the Augmented Mean Group estimator, the results showed that carbon emissions positively impacted the prevalence of HIV, incidence of tuberculosis and malaria incidence. Country-specific estimates revealed that the impact of carbon emissions was different in different countries.

Therefore, the results support the conclusion that carbon emissions are a public health problem in African HIPC's. They do not only indicate environmental degradation but also reflect development processes that increase infectious-disease vulnerability. In debt constrained economies, with limited fiscal space for health and environmental regulation, emission-sensitivity of disease risks will become even more problematic. The study, therefore, calls for the integrated policy approaches that link climate mitigation, urban planning, disease control, sanitation and health financing.

The future research should expand this analysis by adding air pollution measures such as PM_{2.5} exposures, climate measures such as temperature and precipitation and health access at the household level. Also, it should consider mediation through urbanization, sanitation and health spending using appropriate econometric techniques.

Declarations

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Conflict of interest

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Data availability

The study uses publicly available secondary data from World Development Indicators and related international databases.

Ethical consideration

The study uses aggregate country-level secondary data and does not involve human participants or identifiable personal information.

References

Bond, S., & Eberhardt, M. (2009). Cross-section dependence in nonstationary panel models: A novel estimator. *Nordic Econometric Meeting*.

Dumitrescu, E.-I., & Hurlin, C. (2012). Testing for Granger non-causality in heterogeneous panels. *Economic Modelling*, 29(4), 1450-1460. <https://doi.org/10.1016/j.econmod.2012.02.014>

Eberhardt, M., & Teal, F. (2010). Productivity analysis in global manufacturing production. Department of Economics, University of Oxford.

Ebi, K. L., Vanos, J., Baldwin, J. W., Bell, J. E., Hondula, D. M., Errett, N. A., Hayes, K., Reid, C. E., Saha, S., Spector, J., & Berry, P. (2021). Extreme weather and climate change: Population health and health system implications. *Annual Review of Public Health*, 42, 293-315. <https://doi.org/10.1146/annurev-publhealth-012420-105026>

Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. *The Quarterly Journal of Economics*, 110(2), 353-377. <https://doi.org/10.2307/2118443>

Intergovernmental Panel on Climate Change. (2023). Climate change 2023: Synthesis report. IPCC. <https://www.ipcc.ch/report/ar6/syr/>

Liu, Q., Wang, Y., Deng, J., Yan, W., Qin, C., Du, M., et al. (2024). Association of temperature and precipitation with malaria incidence in 57 countries and territories from 2000 to 2019: A worldwide observational study. *Journal of Global Health*, 14, 04021. <https://doi.org/10.7189/jogh.14.04021>

Nguyen, T. T. N., Vu, T. D., Vuong, N. L., Pham, T. V. L., Le, T. H., Tran, M. D., Nguyen, T. L., Künzli, N., & Morgan, G. (2024). Effect of ambient air pollution on hospital admission for respiratory diseases in Hanoi children during 2007-2019. *Environmental Research*, 241, 117633. <https://doi.org/10.1016/j.envres.2023.117633>

Omran, A. R. (1971). The epidemiologic transition: A theory of the epidemiology of population change. *The Milbank Memorial Fund Quarterly*, 49(4), 509-538. <https://doi.org/10.2307/3349375>

Pesaran, M. H. (2004). General diagnostic tests for cross section dependence in panels. *Cambridge Working Papers in Economics*, 0435.

Pesaran, M. H., & Yamagata, T. (2008). Testing slope homogeneity in large panels. *Journal of Econometrics*, 142(1), 50-93. <https://doi.org/10.1016/j.jeconom.2007.05.010>

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Romanello, M., Walawender, M., Hsu, S.-C., Moskeland, A., Palmeiro-Silva, Y., Scamman, D., Ali, Z., Ameli, N., Ayeb-Karlsson, S., Beggs, P. J., Belesova, K., & Costello, A. (2024). The 2024 report of the Lancet Countdown on health and climate change: Facing record-breaking threats from delayed action. *The Lancet*, 404(10465), 1847-1896.

Stern, D. I. (2004). The rise and fall of the Environmental Kuznets Curve. *World Development*, 32(8), 1419-1439. <https://doi.org/10.1016/j.worlddev.2004.03.004>

Westerlund, J. (2007). Testing for error correction in panel data. *Oxford Bulletin of Economics and Statistics*, 69(6), 709-748. <https://doi.org/10.1111/j.1468-0084.2007.00477.x>

World Bank. (2024a). Heavily Indebted Poor Countries (HIPC) Initiative. <https://www.worldbank.org/en/topic/debt/brief/hipc>

World Bank. (2024b). World Development Indicators. <https://databank.worldbank.org/source/world-development-indicators>

World Health Organization. (2023). Climate change and health. <https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health>

World Health Organization. (2024a). Global tuberculosis report 2024. WHO. <https://www.who.int/teams/global-programme-on-tuberculosis-and-lung-health/tb-reports/global-tuberculosis-report-2024>

World Health Organization. (2024b). Vector-borne diseases. <https://www.who.int/news-room/fact-sheets/detail/vector-borne-diseases>

Appendix A: Country-specific carbon-emission coefficients

The appendix reports the country-specific carbon-emission coefficients extracted from the AMG estimates. Values in parentheses are p-values.

Appendix Table A1. Country-specific carbon-emission effects on infectious diseases

Country	CE-HIV	Rank	CE-TB	Rank	CE-Malaria	Rank
Benin	0.020 (0.683)	26th	0.053 (0.000)	16th	0.416 (0.000)	9th
Burkina Faso	0.677 (0.146)	2nd	0.059 (0.005)	15th	0.319 (0.000)	10th
Cameroon	0.457 (0.002)	6th	0.032 (0.597)	19th	1.022 (0.000)	4th
Central African Republic	0.225 (0.041)	10th	0.083 (0.000)	12th	0.199 (0.000)	17th
Chad	0.561 (0.042)	3rd	0.014 (0.000)	27th	0.002 (0.979)	28th
Comoros	0.035 (0.903)	24th	0.104 (0.000)	10th	0.753 (0.141)	5th
Congo Rep	0.206 (0.658)	11th	0.008 (0.011)	28th	0.200 (0.030)	16th
Dem Rep Congo	0.124 (0.241)	16th	0.085 (0.258)	11th	0.064 (0.640)	24th

Ethiopia	0.418 (0.003)	7th	0.113 (0.035)	9th	0.129 (0.809)	21st
Gambia	0.056 (0.711)	22nd	0.017 (0.559)	23rd	1.184 (0.005)	2nd
Ghana	0.197 (0.149)	12th	0.019 (0.244)	22nd	0.269 (0.373)	13th
Guinea	0.079 (0.406)	20th	0.065 (0.163)	13th	0.138 (0.285)	20th
Guinea-Bissau	0.053 (0.899)	23rd	0.060 (0.381)	14th	1.793 (0.052)	1st
Liberia	0.193 (0.000)	13th	0.236 (0.000)	4th	0.004 (0.963)	27th
Madagascar	0.241 (0.276)	8th	0.020 (0.481)	21st	0.482 (0.081)	8th
Malawi	0.147 (0.119)	15th	0.535 (0.000)	2nd	0.295 (0.031)	12th
Mali	0.076 (0.357)	21st	0.029 (0.017)	20th	0.225 (0.004)	14th
Mauritania	0.156 (0.007)	14th	0.017 (0.852)	24th	0.053 (0.776)	25th
Mozambique	0.521 (0.000)	4th	0.049 (0.000)	17th	0.027 (0.573)	26th
Niger	0.495 (0.000)	5th	0.635 (0.000)	1st	0.307 (0.000)	11th
Rwanda	0.237 (0.000)	9th	0.017 (0.905)	25th	0.617 (0.425)	6th
Sao Tome and Principe	0.022 (0.904)	25th	0.162 (0.657)	6th	0.179 (0.822)	18th
Sierra Leone	0.011 (0.882)	27th	0.017 (0.245)	26th	0.067 (0.244)	23rd
Senegal	1.324 (0.000)	1st	0.138 (0.000)	8th	1.066 (0.004)	3rd
Tanzania	0.109 (0.257)	17th	0.036 (0.583)	18th	0.159 (0.463)	19th
Togo	0.101 (0.147)	18th	0.139 (0.117)	7th	0.073 (0.499)	22nd
Uganda	0.002 (0.967)	28th	0.165 (0.000)	5th	0.219 (0.375)	15th
Zambia	0.095 (0.166)	19th	0.432 (0.000)	3rd	0.580 (0.000)	7th