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A PANEL SNAPSHOT OF CLIMATE CHANGE (CO2) EMISSION ON HEALTH RISK: THE CASE OF RELATING SUB-SAHARAN AFRICA TO DIFFERENT COUNTRY REGIONS

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ABSTRACT: *The rising concern that the effect of climate change on population health risk is gradually generating significant attention. This no doubt influenced the exploration of climate change (co2) emission on population health risk in the case of relating African to different income regions. This study made use of fixed panel cross-sectional analysis, descriptive analysis and correlation coefficient index to estimate the study objective which was to investigate the effects of climate change (co2) emission on population health risk among different country income regions from 2000 to 2021 from the World Bank Indicators (WBI) across the selected income countries and region. Findings showed that climate change (Co2) emission per capita, gross domestic product per capita, and food production index, have negative and significant effects on population health risk, whereas, urban population defecation has a positive and significant effect on the population health risk among different country regions. Specifically, carbon dioxide emissions (C02) (c02empc) are highly associated with High-Income countries (HIC) when compared to other income regions. Hence, argued that attention should be to infrastructural sustainability and provision to maintain a clean environment. In addition, more energy should be channelled into food production and livestock production, especially for low-income regions to mitigate the overall effects of carbon dioxide emissions (C02) (c02empc) to tackle food security. Urgent policy actions and responses to air and water quality as useful adaptation strategies in the wider context of climate affect resilience for low-income regions like SSA countries.*

KEYWORDS: carbon dioxide (CO2) emission, health risk, region, pollution and climate change

JEL Classification Codes: I12, I30, Q50, Q51, Q52, Q53, Q54, Q55

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INTRODUCTION

The economies of most high-income countries have to be responsible, especially in the high level of air pollution, such as the carbon dioxide (CO2) emission on health risk across countries and regions in recent time. Interestingly, there are huge arguments establishing how this links to serious population health problems which are responsible for diverse the rising chronic diseases.

Studies across the globe have continued to demonstrate the effects of climate change on the future sustainability of the ecosystem. Interestingly, very few studies have demonstrated the level of these effects comparatively across country regions. This has continued to place most country regions at a very low policy implementation that supports global climate change's effect on health. The outcome of climate changes no doubt has continued to stretch natural resources and as well as threatening environmental quality in many countries due to the rising industrialization among the high-income countries. This also has resulted in improved living standards. Interestingly, recognising the increasing threat of climate change, many countries came together in 2015 to adopt the historic Paris Agreement committing themselves to limit climate change to well below 2° C. According to the Africa Renewal report (2019), about 184 countries formally joined the agreement, including almost every African nation to reduce emissions and build resilience. Yet, studies have continued to place sub-Saharan African countries under serious threat. Studies showed that sub-Saharan Africa is likely to experience increasing temperatures and sea levels, changing precipitation patterns and more extreme weather. It projected regions in Africa within 15 degrees of the equator to experience an increase in tropical nights and longer and more frequent heat waves. This could have a huge, significant impact on the ecosystem as well as deprive the future human population of a healthy environment.

Interestingly, studies showed how mortality is associated with fossil fuels emission especially considering that burning fossil fuels produce greenhouse gasses, which trap radiation from the sun, and are partially responsible for the climate crisis. Bressler (2021) showed that burning fossil fuels produce a toxic cocktail of tiny particles capable of entering our lungs, causing asthma, lung cancer, coronary heart disease and premature death, among other health issues, causing a significant number of excess deaths.

Climate change no doubt aggravates certain urban health risks and inequalities by increasing the frequency and severity of extreme weather events (heatwaves, storms and floods), potentially contributing to air pollution episodes (ground-level ozone and pollen) and disturbing urban ecology. The urban heat island effect (that is; the difference in temperatures between a city centre and the surrounding countryside) also exacerbates heat stress in built-up areas. This has knock-on effects on the indoor environment, energy demand (for ventilation and cooling) and public health (Vardoulakis, Dear and Wilkinson, 2016).

According to the Intergovernmental Panel on Climate Change (IPCC) report (2021), climate change accounts for the rising weather and climate extremes in most regions affecting low, middle, and high-income countries. WHO air pollution and Health report, (2021) reveals that air pollution in both cities and rural areas was estimated to cause 4.2 million premature deaths worldwide per year in 2016 due to exposure to fine particulate matter of 2.5 microns or fewer in diameter (PM2.5), responsible for cardiovascular and respiratory disease, and cancers.

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Unfortunately, despite the global effort from the World Health Organisation and other Development partners adopted a resolution (2015) and the road map (2016) for an enhanced global response to the adverse health effects of air pollution. Besides the several efforts shown by the Health Economic Assessment Tool (HEAT) to assess walking and cycling interventions, the Green tool to raise the importance of green space and health, the Sustainable Transport Health Assessment Tool (STHAT) and the Integrated Transport and Health Impact Modelling Tool (ITHIM) as well as WHO Clean Household Energy Solutions Toolkit (CHEST) to provide countries the tools needed to create or evaluate policies that expand clean household energy access and use, climate change emission has continue to worsen leading to the rising population at health risk in the area of cardiovascular diseases, respiratory diseases, and cancers. Similarly, Bhat, Jiawen and Farzaneh (2021) demonstrated the correlation between air quality and a wide variety of adverse health effects in the disease burden, ranging from subclinical effects to premature death. There is a need to actually estimate the effect of climate change using the carbon emission (c02) proxy on population health risk across different country regions. In other words, this study provides a panel cross-sectional approach of investigation that show comparatively different countries in their different income and regional group against SSA countries to provide further theoretical and empirical references that could strengthen policy and government collaboration on climate change issues across countries and regions.

LITERATURE

Studies have shown that economic growth and population health have significantly improved among high-income countries with a consistent decline in mortality rate, increased life expectancy, and expansion of immunisation coverage, unfortunately, the increasing air pollution, including carbon dioxide (CO_2) emission, is causing grievous health problems and accompanying heavy economic burdens on healthcare across regions (Chen, Zhuo, Xu, and Gao, 2019)

In 2020, the United Nation State of the Climate in Africa reported that adverse consequences of climate change are concentrated in regions with relatively tropical climates, where a disproportionately large number of low-income countries are located. Interestingly, the African Climate Policy Centre projects that the Gross Domestic Product in the five African subregions would suffer a significant decrease because of a global temperature increase. For scenarios ranging from a 1 °C to a 4 °C increase in global temperatures relative to pre-industrial levels, the continent’s overall GDP is expected to decrease by 2.25% to 12.12%. West, Central and East Africa exhibit a higher adverse impact than Southern and North Africa.

In addition, increases in temperature and changes in rainfall patterns also significantly affect population health across Africa. Warmer temperatures and higher rainfall increase habitat suitability for biting insects and the transmission of vector-borne diseases such as dengue fever, malaria and yellow fever. Evidence has revealed that new diseases are emerging in regions where they were previously not present. In 2017, about 93% of global malaria deaths occurred in Africa. Malaria epidemics often occur after periods of unusually heavy rainfall. In addition, warming in the East African highlands is allowing malaria-carrying mosquitoes to survive at higher altitudes.

Despite how health and well-being are affected by many factors such as poor health status, disability, disease or death and environmental issues among other factors yet, studies have also

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revealed that environmental pollution affects the geographical distribution of many infectious diseases, as do natural disasters. Studies across the globe have articulated the effects of climate change on population health risks from different perspectives.

For example, Serdeczny, Adams, Baarsch, Coumou, Robinson, Hare, Schaeffer, Perrette and Reinhardt (2016) demonstrated that they felt the repercussions of climate change in various ways throughout both natural and human systems in Sub-Saharan Africa. Climate change projections for this region point to a warming trend, particularly in the inland subtropics; frequent occurrence of extreme heat events; increasing aridity; and changes in rainfall, with a particularly pronounced decline in southern Africa and an increase in East Africa.

The study further revealed that the SSA countries region could experience as much as one meter of sea-level rise by the end of this century under a 4 C warming scenario. Sub-Saharan Africa's already high rates of undernutrition and infectious disease are expected to increase compared to a scenario without climate change. Particularly vulnerable to these climatic changes are the rained agricultural systems on which the livelihoods of a large proportion of the region's population currently depend. As agricultural livelihoods become more precarious, the rate of rural-urban migration is expected to grow, adding to the already significant urbanisation trend in the region. Also, the movement of people into informal settlements may expose them to a variety of risks different but no less serious than those faced in their place of origin, including outbreaks of infectious disease, flash flooding and food price increases.

Chaabouni and Saidi (2017) examined the causal relationship between carbon dioxide (CO2) emissions, health spending and GDP growth for 51 countries (divided into three groups of countries: low-income countries; a group of countries with lower and upper middle income; a group of middle-income countries) covering the annual period of 1995–2013. The study which adopted the Dynamic simultaneous-equations models and the generalised method of moments (GMM) techniques revealed that there is a bidirectional causality between CO2 emissions and GDP per capita, between health spending and economic growth for the three groups of estimates. The findings further demonstrated that there is unidirectional causality from CO2 emissions to health spending, except in low-income group countries despite that health plays an important role in GDP per capita, the study found how this has continued to limit its effect on a growing deterioration in the quality of the environment.

Hansen, Bender, Andersen, Sorensen, Bonlokke, Boushuizen, Becker, Diderichsen, and Loft (2018) estimated the health benefits of reduced exposure to vehicle emissions assessed as NO2 at the residence among the citizens of Copenhagen Municipality, Denmark. The used residential NO2 concentrations were modelled by the use of chemistry transport models to calculate contributions from emission sources to air pollution. The DYNAMO-HIA model was applied to the population of Copenhagen Municipality by using NO2 concentration estimates combined with demographic data and data from nationwide registers on the incidence and prevalence of selected diseases, cause-specific mortality, and total mortality of the population of Copenhagen. We used exposure-response functions linking NO2 concentration estimates at the residential address with the risk of diabetes, cardiovascular diseases, and respiratory diseases derived from a large Danish cohort study with most subjects living in Copenhagen between 1971 and 2010. Different scenarios were modelled to estimate the dynamic impact of NO2 exposure on related diseases and the potential health benefits of lowering the NO2 level in the Copenhagen Municipality. Interestingly, findings showed that lowering NO2 exposure

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by 20% would increase disease-free life expectancy for the different chronic diseases by 0.3–0.5 years and increases life expectancy.

Morandeira, Castessana, Cardo, Salomone, Vadell, and Rubio (2019) diagnosed human health risks in San Martín, an urban district in Buenos Aires, Argentina. They estimated risk by combining four hazard indexes (water and air pollution, and mosquito and rodent infestation) and a vulnerability index. Each index got by integrating environmental and socio-demographic layers in a Geographic Information System. It assessed spatial autocorrelation for each hazard, vulnerability, and risk index using Moran's tests. Also, spatial associations between pairs of variables are addressed through Geographically Weighted Regressions. A sensitivity analysis checked the robustness of hazard and vulnerability. San Martín district, 83.3% of the population is exposed to relatively high levels of at least one hazard; 7.4% are exposed to relatively high levels of all hazards (11.5% of the total area) and only 16.7% lives live in areas of relatively low levels of all hazards (15.4% of the total area). Areas where hazard intensity was relatively high corresponded to those areas where the most vulnerable population lives, enhancing human health risk. The models for hazards and vulnerability were reasonably robust to changes in the weights of the variables considered. Findings highlighted the spatially heterogeneous nature of human health risk in an urban landscape, and reveal the location of critical risk hotspots where reduction or mitigation actions should be focused.

In contrast, Siddique and Kiani (2020) explored the relationship between industrial pollution and health using the panel of middle-income countries (MIC) from 1990 to 2016. Adopting two indicators of health status, namely life expectancy and infant mortality, and two indicators of industrial pollution, namely carbon dioxide emissions and nitrous oxide emissions. Fixed effects (FE) technique on the grounds of the Hausman test, however, revealed that industrial pollution decreases life expectancy and increases infant mortality. The findings also showed that the adverse impact of industrial pollution is greater in lower-middle-income countries (LMIC) compared to upper-middle-income countries (UMIC). Policies focus should be towards mitigating industrial pollution burden.

Ehigiamusoe, Lean, and Smyth (2020) examined the role of energy consumption in moderating the carbon dioxide emissions-income nexus in 64 middle-income countries. Employing multiplicative interaction models to compute the marginal effects of real GDP per capita on carbon dioxide emissions at various levels of energy consumption. Findings showed that there was no significant evidence that energy consumption moderates the relationship between income and carbon emissions in the panel. However, in focusing on specific countries, findings showed that energy consumption moderates the nexus between carbon emissions and income in roughly one-third of our sample and that the moderating effect is negative in about one-fifth of the sample. Hence, found no significant evidence exists that energy consumption moderates the relationship between income and carbon emissions in the panel.

Manisalidis, Stavropoulou, Stavropoulos, and Bezirtzoglou (2020) argued that climate change impact is more common in public and individual health due to increased morbidity and mortality associated with environmental pollution. Manisalidis et al. (2020) argument is that there are many pollutants that are major factors in disease in humans which includes Particulate Matter (PM), particles of variable but tiny diameter, which penetrate the respiratory system via inhalation, causing respiratory diseases, cardiovascular diseases, reproductive and central nervous system dysfunctions, and cancer. Although ozone in the stratosphere plays a protective role against ultraviolet irradiation, it is harmful when in high concentration at ground level,

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also affecting the respiratory and cardiovascular systems. Manisalidis et al (2020) also maintained that nitrogen oxide, sulfur dioxide, Volatile Organic Compounds (VOCs), dioxins, and polycyclic aromatic hydrocarbons (PAHs) are all considered air pollutants that are harmful to humans.

While carbon monoxide can even provoke direct poisoning when breathed in at high levels. Heavy metals such as lead, when absorbed into the human body, can lead to direct poisoning or chronic intoxication, depending on exposure. Diseases occurring from the aforementioned substances include principally respiratory problems such as Chronic Obstructive Pulmonary Disease (COPD), asthma, bronchiolitis, and also lung cancer, cardiovascular events, central nervous system dysfunctions, and cutaneous diseases (Manisalidis et al., 2020).

Bhat, Jiawen and Farzaneh (2021) investigated the effects of Air Pollution Health Risk Assessment (AP-HRA) on conducting AP-HRA for different scenarios. The study, however, adopted seven widely used AP-HRA tools in exploring how the health hazards of air emissions and their origins are measured and how air pollution-related effects are quantified. Considering their spatial resolution, technological factors, pollutants addressed, geographical scale, quantified health effects, method of classification, and operational characteristics. Employing a comparative analysis using the SWOT (strengths, weaknesses, opportunities, and threats) method found that a significant correlation between air quality and a wide variety of adverse health effects emphasising a considerable role of air pollution in the disease burden in the general population ranging from subclinical effects to premature death.

Rocque, Beaudoin, Ndjaboue, Cameron, Poirier-Bergeron, Poulin-Rheault, Fallon, Tricco and Witteman (2021) examined the health effects of climate change through a synthesis of systematic reviews across geographical regions. Findings revealed that climate change is associated with adverse human health outcomes with rising in the near future, in temperature and an increase in climate-change-related events such as extreme weather events and worsened air quality.

Bressler (2021) argued that, though many studies project that climate change can cause a significant number of excess deaths. Yet, in integrated assessment models (IAMs) that determine the social cost of carbon (SCC) and prescribe optimal climate policy, human mortality is limited and not updated to the latest scientific understanding. Bressler (2021) extends the DICE-2016 IAM explicitly include temperature-related mortality effects by estimating a climate-mortality damage function and also exploring the mortality cost of carbon (MCC), which estimates the number of deaths caused by the emissions of one additional metric ton of CO2. Findings, however, demonstrated that the overall effect of climate on the fertility rate is not yet clear, even directionally. In keeping with the rest of the analysis, maintained that the effect of climate change on fertility should not view as a projection of the effect of climate change on population levels. Instead, it should be viewed as a projection of the effect of climate change on human mortality and the welfare consequences of this effect.

Despite the entire argument on the effect of climate change on health care risk, the evidence seems not to have shown enough across regions to reveal the volume of the African contribution to climate change effects on health risk when compared to another region. This study, however, argues that there is a need to show a comparative description of climate change affects health across different income countries which includes an increase in infectious diseases, respiratory disorders, heat-related morbidity and mortality, undernutrition because of

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food insecurity, and adverse health outcomes. However, considering the different levels of country development. This study focused significant attention on comparative statistics among countries on the level of climate change effect on health risk across different income regions.

METHODOLOGY

The Health Promotion Model developed by Nola J. Pender (1982) provides a theoretical framework for this study. Considering its bases for preventative health measures and how it has been adopted into a theoretical model for promoting well-being and healthy lifestyles. This also connects to green economic thinking with regard to climate change's effect on population health and health risk associated with all environmental health challenges. It is on these bases that this theory provides a connection to the panel estimation techniques.

The analysis of panel or longitudinal data is one of the most active and innovative econometrics approaches, as it provides a rich environment for cross-sectional estimation across panels based on estimation techniques and theoretical results. Hsiao (2014) Baltagi (2008) and Andrew et al. (2013) list several advantages of using panel data, instead of pure cross-section or pure time series data. This advantage includes the techniques of pooling large samples, allowing for more degrees of freedom, more variability, more information and less multi-collinearity among the variables.

In more practical terms, the panel has the advantage of having N cross-section and T time series observations, thus contributing to NT observations. This comes with the possibility of controlling for an individual country or time heterogeneity, which pure cross-section or pure time series data cannot afford hence, opens up the scope for dynamic analysis.

Researchers have been able to use panel estimation techniques to examine issues that could be studied in a large number of cross-sectional units as found in many applications that focused on variations or heterogeneity of health policy changes, and the dynamic of the country's behaviour which help in sub-Saharan African countries studies as well. This mythology, no doubt, provides better-suited techniques for examining climate change emissions and the population at health risk across income countries with a specific observation of African countries.

Hence, to estimate the study objective, model (1) specified functionally:

$$lnpophrisk = f(urbpop + c02em + opnd + gdppc + fdprindex + lpindex + safeH20 + safesanit + i.incomecountries) \quad 1$$

Model (1) thus specified econometrically as;

$$lnpophrisk_{it} = \alpha_0 + \beta_1 urbpop + \beta_2 c02em + \beta_3 opnd + \beta_4 gdppc + \beta_5 fdprindex + \beta_6 lpindex + \beta_7 safeH20 + \beta_8 safesanit + \beta_9 i.incomecountries + \phi_1 + \epsilon_{it} - \mu_{it} \quad 2$$

Where the term $\mu_1 > 0$, measures income countries across regions and other intervening indicators. They constrained it to be always non-negative. The above model was then re-written as:

$$lnpophrisk_{it} = \alpha_0 + \beta_1 urbpop + \beta_2 c02em + \beta_3 opnd + \beta_4 gdppc + \beta_5 fdprindex + \beta_6 lpindex + \beta_7 safeH20 + \beta_8 safesanit + \beta_9 i.incomecountries + \phi_1 + \delta_{it} \quad 3$$

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Where the new intercept $\alpha_1 = (\alpha - \mu_1)$ is now health risk measured by the population at health risk and ϕ_1 was the unobserved country heterogeneity that affected outcomes.

Therefore, the random effects model simply suggests that the unobserved country heterogeneity $\phi 1$ expressed in the idiosyncratic disturbance.

$$lnpophrisk_{it} = \alpha_0 + \beta_1 urbpop + \beta_2 c02em + \beta_3 opnd + \beta_4 gdppc + \beta_5 fdprindex + \beta_6 lpindex + \beta_7 safeH20 + \beta_8 safesanit + \beta_9 i.incomecountries + \phi_1 + \epsilon_{2it} \quad 4$$

The random effects model puts ϕ into the idiosyncratic disturbances because it changes across “t” as well as across “i”. As such, the fixed effects model was, however, transformed into a vector as:

$$lnpophrisk_{it} = \alpha_0 + \beta_1 urbpop + \beta_2 c02em + \beta_3 opnd + \beta_4 gdppc + \beta_5 fdprindex + \beta_6 lpindex + \beta_7 safeH20 + \beta_8 safesanit + \beta_9 i.incomecountries + \phi_1 + \epsilon_{1it} \quad 5$$

Therefore, to estimate the effects of climate change emission on the population at health risk across income counties region, a model.

$$lnpophrisk_{it} = \alpha_0 + \beta_1 urbpop + \beta_2 c02em + \beta_3 opnd + \beta_4 gdppc + \beta_5 fdprindex + \beta_6 lpindex + \beta_7 safeH20 + \beta_8 safesanit + \beta_9 i.incomecountries + \phi_1 + \delta_{it} \quad 6$$

The estimation procedure for the study followed a statistical test of panel estimation technique and since the various region are heterogeneous, the fixed effect estimation applied and the consistency and efficiency of this model improved by adjusting the standard error estimates in order to capture more robust findings (t-stat and f-prob). This should reduce the heterogeneity bias that may occur. We compared the random and fixed effects approach, using Hausman’s test to select the most appropriate model. Hence, data for the selected regions were extracted first from the World Bank Indicator to an Excel spreadsheet, and imported into the STATA spreadsheet for a series of Pre-estimation tests such as

Hausman test is a statistical test to select whether the most appropriate Fixed Effect or Random Effect model used.

If Result:

H_0: Select RE ($p > 0.05$)

H_1: Select FE ($p < 0.05$)

The rho statistics value explains the variances that occur due to differences across time (within units). Better specifically known as the interclass correlation, and tells how strongly the observations (SSA Countries) within each unit resemble each other. Estimates like *sigma_u* are further adopted to explain the standard deviations of residuals within groups while *sigma_e* explains the standard deviation of residuals overall due to the observation.

The square of the coefficient of determination R^2 overall or the measure of goodness of fit was used to judge the explanatory power of explanatory variables on the dependent variable. The R^2 overall called the coefficient of determination showed the amount of variation in the dependent variable explained by the explanatory variables, though this time was different from the normal R^2 in ordinary least square (OLS) techniques. While the ***z-statistic*** was used to determine the reliability/statistical significance of each variable coefficient. Here, the absolute z-value of each coefficient was compared with 1.96 and if greater than 1.96, such variable

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possessing the coefficient was accepted as statistically significant, fit for inferences and for forecasting.

This study made use of panel cross-sectional data for the analysis of specified models where data was retrieved from the World Bank Indicators (WBI) 2021. The data coverage was from 2000 to 2021, across the selected income countries.

RESULTS PRESENTATION AND DISCUSSION

Pre-Estimation Test

The model to be estimated is a panel data series model, and this implies the necessity of Hausman's test to determine between the fixed effects or random effects modelling, which is most appropriate. while taking into consideration the differences in the countries of analysis. The result of Hausman's test is shown below in table 4.1, with the null hypothesis being that the difference in coefficients is not systematic, so prob>chi^2< 0.05, hence reject Ho_1 meaning that the fixed effects model can be applied, but if prob > chi^2> 0.05, the Ho_1 accepted and by implication the random effects model will apply.

Table 4.1: Hausman's Test Result

Test: Ho: difference in coefficients not systematic
chi2(0) = (b-B)'[(V_b-V_B)^(-1)](b-B)= 0.00
Prob>chi2 = (V_b-V_B is not positive definite)

Source: *authors' computation 2022.*

As could be seen above, the prob > chi^2 is less than 0.00 and hence less than 0.05, therefore the Ho is accepted and we conclude that the fixed effects model is most appropriate for this analysis. However, the need still remains to run the random effects mode to serve as a basis for comparison if the need arises.

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Table 4.2: Panel Descriptive Analysis

Variable	Obs	Mean	Std. Dev.	Min	Max
urbanpop	176	61.21895	18.51063	27.3813	81.75539
c02empc	176	5.403988	3.632413	.7170688	12.0931
opndefup	176	2.777204	4.539908	.0000322	21.8017
chxpgdp	176	7.343376	2.871154	3.201425	12.55222
pophrisk	176	20.46649	20.93811	0	73.25092
gdppc	176	14798.06	14117.07	453.2376	45453.05
fdprindex	176	.7204862	1.711779	.124125	7.637703
lpindex	176	1.248172	3.659965	.1202586	15.62795
safeh2o	176	53.6506	39.54178	0	97.66899
safesanit	176	44.97525	27.73119	0	87.30121

Source: *authors' computation 2022.*

Table 4.2 showed the different panel variables in descriptive statistics employed to measure (C02) emission (*c02empc*) which is the Carbon dioxide emissions (C02) stemming from the burning of fossil fuels and manufacturing cement including carbon dioxide produced during the consumption of solid, liquid, and gas fuels and gas flaring employed to measure climate change in this case which is at an average of 54 per cent among income countries from 2000 to 2021.

While the population at health risk (*pophrisk*) which is designed to proxy morbidity measures the number of persons who have an illness or disease per 100000 of the population at an average of 20 per cent among income countries from 2000 to 2021.

In addition, Urban population (% of the total population) (*urbanpop*) refers to people living in urban areas as defined by national statistical offices at an average of 61 per cent among income countries from 2000 to 2021. Similarly, People practising open defecation, (% of urban population) (*opndefup*) which are the percentage of the population defecating in the open, such as in fields, forest, bushes, open bodies of water, on beaches, in other open spaces or disposed

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of with solid waste on average account for 28 per cent among income countries from 2000 to 2021.

While, People using safely managed sanitation services (% of the population) (*safesanit*) using improved sanitation facilities that are not shared with other households and where excreta is safely disposed of in situ or transported and treated offsite as well as improved sanitation facilities which include flush/pour flush to piped sewer systems, septic tanks or pit latrines on average account for 45 per cent among income countries from 2000 to 2021.

In addition, the Food production index (*fdprindex*) which covers edible food crops and that contain nutrients on average, account for 7 per cent among income countries from 2000 to 2021. Whereas, the Livestock production index (*lpindex*) which includes meat and milk from all sources, dairy products such as cheese, eggs, honey, raw silk, wool, and hides and skins on average account for 12 per cent among income countries from 2000 to 2021.

Also, the percentage of people using drinking water (*safeh20*) from an improved source that is accessible on premises, available when needed and free from faecal and priority chemical contamination. These improved water sources include piped water, boreholes or tube wells, protected dug wells, protected springs, and packaged or delivered water on average accounting for 54 per cent among income countries from 2000 to 2021.

Also, Current health expenditure (% of GDP) (*chxpgdp*) measures the level of resources channelled to health relative to other uses. It shows the importance of the health sector in the whole economy and indicates the societal priority which health is given measured in monetary terms on average accounting for 73 per cent among income countries from 2000 to 2021. While, GDP per capita (*gdppc*) which measures socioeconomic status such as its correlation to lower levels of education and its effects on health on average, account for 147 per cent among income countries from 2000 to 2021.

Table 4.3: Correlation Coefficient Index of carbon emission and Population at Health Risk

	c02empc	urbanpop	opndefup	chxpgdp	pophrisk	gdppc	fdprin~x	lpindex	safeh2o	safesa~t
c02empc	1.0000									
urbanpop	0.7513	1.0000								
opndefup	-0.6636	-0.7752	1.0000							
chxpgdp	0.8400	0.8206	-0.5714	1.0000						
pophrisk	-0.6376	-0.6732	0.4965	-0.6975	1.0000					
gdppc	0.8979	0.7395	-0.5410	0.9466	-0.6181	1.0000				
fdprindex	-0.3494	-0.3978	0.3335	-0.2427	0.1187	-0.2953	1.0000			
lpindex	-0.3484	-0.4006	0.3494	-0.2228	0.1102	-0.2813	0.9975	1.0000		
safeh2o	0.5972	0.8172	-0.5949	0.6893	-0.5372	0.6565	-0.2024	-0.2160	1.0000	
safesanit	0.8853	0.6362	-0.5340	0.8787	-0.5640	0.9195	-0.3295	-0.3084	0.4976	1.0000

Source: *authors' computation 2022.*

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Table 4.3 depicts the correlation coefficients between carbon emission and the population at Health Risk. The coefficients indicate that the Urban population (% of the total population) (*urbanpop*) which refers to people living in urban areas, has a positive correlation with Carbon dioxide emissions (C02) (*c02empc*). This implies that the Urban population (% of the total population) (*urbanpop*) moves in the same direction as the burning of fossil fuels because of the effects of carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring. In other words, the coefficient value 0.7513 shows the strength of the relationship between the Urban population (% of the total population) (*urbanpop*) and Carbon dioxide emissions (C02) (*c02empc*) employed to measure the climate change effect. So, when the Urban population (% of the total population) (*urbanpop*) increases, Carbon dioxide emissions (C02) (*c02empc*) also increase by 75.13 per cent.

Whereas, open defecation, (% of urban population) (*opndefup*) which are the percentage of the population defecating in the open, such as in fields, forest, bushes, open bodies of water, on beaches, in other open spaces or disposed of with solid waste have a negative correlation with Carbon dioxide emissions (C02) (*c02empc*) among different income countries from 2000 to 2021. The result implies that open defecation (% of urban population) (*opndefup*) increases. Carbon dioxide emissions (C02) (*c02empc*) rather decrease by 0.6636, which is at 66.36 per cent.

In addition, current health expenditure (% of GDP) (*chxpgdp*) which measures the level of resources channelled to health relative to other uses has a positive correlation with Carbon dioxide emissions (C02) (*c02empc*) by 0.8400 which is at 84 per cent. Similarly, GDP per capita (*gdppc*) which measures socioeconomic status such as its correlation to lower level of education and its effects on health, people using drinking water (*safeh20*) from an improved source that is accessible on premises, available when needed and free from faecal and priority chemical contamination and sanitation services (% of the population) (*safesanit*) all have a positive correlation with Carbon dioxide emissions (C02) (*c02empc*) by 0.8979 which is at 89.8 per cent, 0.5972 which is at 59.7 per cent and 0.8853 which is at 88.5 per cent respectively.

Unfortunately, population at health risk (*pophrisk*) which proxy morbidity measures of persons who have an illness or disease per 100000 of the population have a negative correlation with Carbon dioxide emissions (C02) (*c02empc*) among different income countries from 2000 to 2021 by 0.6376 which is at 63.8 per cent. Other indicators with a negative association with carbon dioxide emissions (C02) (*c02empc*) include; Food production index (*fdprindex*) which covers edible food crops that contain nutrients by 0.3494 which is at 34. 9 per cent and the livestock production index (*lpindex*) which includes meat and milk from all sources, dairy products such as cheese, and eggs, honey, raw silk, wool, and hides and skins by 0.3484 which is at 34. 8 per cent.

This clearly, showed that urban population, current health expenditure to GDP, GDPPC, safe h20 and sanitation are associated with Carbon dioxide emissions (C02) (*c02empc*) perhaps climate change issues, considering how this study evidence reveals that open defecation, the population at health risk, food production, and livestock production are not associated with Carbon dioxide emissions (C02) (*c02empc*) as have demonstrated by previous studies. This also shared a similarity with the evidence provided by Chaabouni and Saidi (2017), Siddique and Kiani (2020).

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Table 4.4: Panel Fixed Effects of Carbon dioxide emissions (C02) (*c02empc*) on Health Risk among Different Income-group countries.

lnpophrisk:	Coef.	t-stat	P>|t|
urbanpop	**.196971**	**0.23**	**0.821**
c02empc	**-9.378275**	**-2.95**	**0.004**
opndefup	**.925894**	**2.36**	**0.020**
gdppc	**-.0037808**	**-7.88**	**0.000**
fdprindex	**-33.56157**	**-2.00**	**0.047**
lpindex	**15.02733**	**1.90**	**0.060**
safeh2o	**-.0572378**	**-0.90**	**0.369**
safesanit	**-.0417426**	**-0.19**	**0.850**
Id OECD countries (base category)			
2 ECA countries	-59.42538	-7.18	0.000
3 LAC countries	-155.5685	-5.90	0.000
4 MNA countries	-109.5763	-6.13	0.000
5 HKG (SAR), China	-164.4505	-5.27	0.000
6 SSA countries	-170.1266	-5.91	0.000
7 EAS countries	-117.342	-6.05	0.000
8 HIC	30.83515	5.11	0.000
_cons	216.0447	4.30	0.000
Rho stat= .82858491	F(15,139)= 40.33	Prob> F = 0.0000	R-sq: within= 0.8131 Between=0.3084 Overall=0.2448

Source: *authors' computation 2022.*

Table 4.4 depicts the Panel Fixed Effects of Carbon dioxide emissions (C02) (*c02empc*) on Health Risk among Different Income-group countries. The findings showed that climate change (Co2) emission show negative but significant effects on the population at health risk by 0.9378275, which is about 94 per cent at a 5% significant level across country regions.

This is further followed by gross domestic product per capita (*gdppc*) which also impact the population at health risk by 0.0037808 which is about 0.4 per cent at a 5% significant level across country regions and food production index with a negative effect on the urban population at health risk at 33.56157 accounting for 34 per cent at 5% significant level across country regions. Interestingly, these three indicators seem to have been responsible for the rising urban population at health risk. However, due to health campaigns on defecation, results show that urban population defecation has a positive on the urban population at health risk at 0.925894 (92 per cent) at a 5% significant level while, the population using safe water, the population using safe sanitation, urban population growth rate among other show to be significant at 5 per level.

Findings showed that the Prob> F of 0.000 suggests that the overall model is significant, hence the study can conclude that the model is robust and the results thereof, are reliable. While the rho statistics tells us that 83% of the variance is due to difference across panel while, treating the OECD region as the base category, the findings also show that region like Europe and

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Central Asia (ECA), Latin America & Caribbean (LAC), Middle East & North Africa (MNA), Hong Kong SAR, China (HKG), Sub-Saharan Africa (SSA), East Asia & Pacific countries (EAS), and High-Income countries (HIC) all have significant effects on the urban population at health risk as evidenced in the t-value statistics that is higher than 2 (1.96) with a probability value that is less than 0.05 hence significant at a 5% significant level among these regions.

CONCLUSION, SUMMARY OF FINDINGS AND POLICY RECOMMENDATIONS

This study explored the panel snapshot of climate change (co2) emission on population health risks relating Africans to different income regions. This study made use of fixed panel cross-sectional analysis, descriptive analysis and correlation coefficient index to estimate the study aim. Secondary data retrieved from the World Bank Indicators (WBI) between 2000 to 2021 across the selected income Countries and regions like Europe and Central Asia (ECA), Latin America & Caribbean (LAC), Middle East & North Africa (MNA), Hong Kong SAR, China (HKG), Sub-Saharan Africa (SSA), East Asia & Pacific countries (EAS), and High-Income countries (HIC).

The findings showed that climate change (*Co2*) emission per capita, gross domestic product per capita, and food production index, have negative and significant effects on population health risk, whereas, urban population defecation has a positive and significant effect on the population health risk among different country regions. Specifically, Carbon dioxide emissions (C02) (*c02empc*) are highly associated with High-Income countries (HIC) when compared to other income regions. This study, however, maintained that efforts intensified to address the rising challenges of urban population defecation, which could be because of flooding, resource overstretch, accommodation challenges, rising kidnapping in rural areas, and rural poverty among others influencing rural-urban drift. We should give attention to infrastructural sustainability and provision to maintain a clean environment considering the implication of urban population defecation on health risks across the country region. In addition, this study further maintains that more energy should be channelled into food production and livestock production, especially for African countries, to mitigate the overall effects of carbon dioxide emissions (C02) (*c02empc*) to tackle food security. The finding clearly showed that climate change impacts lower-income countries region, hence it is among those likely to be vulnerable to a wider range of climate change exposures, hence urgent policy actions and responses to air and water quality as useful adaptation strategies in the wider context of climate affects resilience for low-income regions like SSA countries.

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