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THE ECONOMIC STRAIN OF CLIMATE CHANGE: ACCOUNTING FOR EXTREME HEAT AND HEALTHCARE SPENDING

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ABSTRACT

This study investigated the financial burden of climate change on public health systems, with a specific focus on how extreme heat days and diurnal temperature range affect current health expenditure as a percentage of GDP across countries from 2000 to 2023. The main objective was to examine the impact of climate-induced heat variations on government health spending, while the specific objectives included analyzing the effect of extreme heat days (EXHD), diurnal temperature range (DTR), and population (POP) on health expenditure. An ex post facto research design was adopted, utilizing panel data sourced from the World Bank. Variables were analyzed using descriptive statistics, correlation analysis, and multiple regression models. The dependent variable was current health expenditure, proxied by Current Health Expenditure (% of GDP), while the key independent variables were EXHD (computed as the number of extreme heat days normalized and expressed as a percentage) and DTR (measured as a dummy variable indicating daily temperature variability). Population (POP) served as a control variable. Findings from the regression analysis revealed a statistically significant and positive relationship between extreme heat days and health expenditure ($\beta = 0.3616$, $p < 0.001$), indicating that rising heat-related incidents are associated with increased government spending on health services. Conversely, diurnal temperature range had an insignificant effect ($p > 0.05$), suggesting that short-term temperature fluctuations may not significantly influence public health budgets. Correlation analysis further supported the positive association between EXHD and health expenditure ($r = 0.6962$). The study concludes that climate-induced extreme heat exerts a considerable financial burden on national health systems, compelling governments to invest more in adaptive health responses. However, many countries still underinvest in climate-resilient health infrastructure. Key recommendations include the integration of climate risk into national health planning, establishment of heatwave early warning systems, and enhanced international support for low- and middle-income countries to strengthen their adaptive capacity. Future research should explore the long-term economic costs of climate-related health events and support real-time data collection to inform evidence-based policies.

***Key words:** Climate Change, Extreme Heat Days, Diurnal Temperature Range, Health Expenditure, Public Health, Government Spending*

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1. INTRODUCTION

Rising temperatures due to extreme heat events have been closely linked to an increase in healthcare costs. These costs stem from the spike in heat-induced health conditions and the aggravation of pre-existing illnesses, which lead to more frequent visits to outpatient clinics and emergency rooms, hospitalizations, and broader medical expenses for conditions such as heatstroke and heat exhaustion. Since the Industrial Revolution, global energy use and greenhouse gas emissions have escalated, driving a persistent rise in global temperatures. This warming trend has brought about more frequent and intense extreme weather events—particularly heatwaves (Fischer et al., 2012; Change, 2014; Lee et al., 2014a; Guo et al., 2022; Rana et al., 2022). Climate change has significantly affected both economic productivity and public well-being, with substantial evidence pointing to its negative impact on economic development. For example, Dell et al. (2009) estimated that each 1°C rise in temperature could decrease economic output by up to 8.5%, a reduction largely attributed to diminished labor efficiency and economic vitality under adverse weather conditions.

The broader economic decline is shaped by multiple interrelated factors, including worsening public health outcomes (Bleakley, 2010; Cho, 2017; Chen et al., 2022a), reduced agricultural productivity (Shah & Steinberg, 2017), and even socio-political unrest (Acemoglu et al., 2001; Dell et al., 2012). As such, climate change encompasses a complex web of socio-economic challenges (Engström, 2016; López & Yoon, 2020). Among the many effects of climate change, its toll on human health stands out. Experts have described climate change as the leading global health threat of the 21st century (Costello et al., 2009). Much of the current research has concentrated on how extreme weather affects neonatal health and mortality rates (Marcotte, 2015; Chalfin et al., 2019). However, a broader understanding of how extreme temperatures influence general health outcomes remains undeCENGDPveloped. This gap is largely due to two main issues: limited access to disease incidence data (Graff Zivin & Neidell, 2013), and the increased mobility of people, which allows them to alter their exposure to extreme temperatures by adjusting their daily routines or relocating (Marchiori et al., 2012; Cattaneo & Peri, 2016). These factors complicate efforts to accurately assess the health impact of extreme heat. Unlike studies that focus solely on vulnerable groups such as infants or the elderly, analyzing morbidity across the general population offers a more holistic view of the healthcare costs attributable to extreme heat.

Nigeria, as Africa's most populous country and largest economy, has increasingly felt the impact of extreme heatwaves in recent years. The Nigerian Meteorological Agency has reported record-breaking temperatures during summer months, surpassing historical norms in various regions. Given Nigeria's large and climatically diverse population, the economic and health consequences of extreme heat are particularly acute. Therefore, analyzing Nigeria's experience with extreme heat is key to understanding the broader effects of climate change. This research uses data from the Nigerian Health and Nutrition Survey (NHNS) to explore the influence of extreme heat on health outcomes. The methodology includes calculating the number of heatwave days at the city level. Because extreme heat stems from global climate dynamics rather than local actions, such weather events can be considered exogenous. One challenge, however, is the potential for migration in response to heat stress, which may affect the sample. To address this, the study excludes individuals likely to relocate for climatic reasons. The findings reveal a causal link between extreme heat and increased illness rates, disease severity, hospital admissions, and rising healthcare expenses. Each additional heatwave day corresponds with an estimated increase of approximately NGN [converted equivalent] million in medical costs. Further analysis indicates that climate-related migration has minimal influence on these results. Disaggregated data show that women, rural populations, and the unemployed are more vulnerable to heat-related health problems. Moreover, income and education levels serve as protective factors, while older adults face higher risks. Beyond physical health, extreme heat also affects behavior by reducing outdoor mobility and increasing time spent indoors, particularly affecting those who walk for their daily commutes.

This study offers several contributions to existing literature. Firstly, it provides an economic estimate of the health-related costs of extreme heat. A major difficulty in such assessments is creating accurate local indices for extreme temperatures, as the definition of "extreme" varies across different regions. While some studies consider temperatures above 30°C to be extreme (Karlsson & Ziebarth, 2018), such uniform thresholds fail to reflect regional climate adaptation. To overcome this, the study defines extreme heat using the 95th percentile of local temperature distributions from the previous three years, ensuring region-specific relevance. The analysis also considers adaptive behaviors, recognizing that people often relocate when temperatures become intolerable (Cameron & McConnaha, 2006). Since such migrants tend to be more aware of climate risks, excluding them helps prevent underestimation of health costs. Secondly, the study explores the various pathways through which extreme heat influences health. While direct physiological effects are well documented, this research uncovers significant socio-behavioral mechanisms. For instance, higher temperatures reduce physical activity and change the distribution of indoor versus outdoor time, which in turn affects commuting habits. Thirdly, by incorporating morbidity data, the study enhances the estimation of the broader social costs associated with extreme heat. While mortality statistics are often emphasized in policy discussions, morbidity provides a more nuanced picture of how climate change affects day-to-day health and economic systems. Although the costs associated with illness are generally lower than those linked to mortality, they still represent a meaningful baseline for assessing the broader economic impacts of climate-related health issues. These findings are vital for shaping public health strategies, fiscal planning, and national development policies aimed at building resilience to climate change.

1.1 Objectives

The primary aim of this study is to evaluate how extreme heat influences health-related expenditures in Nigeria. Specifically, the objectives are to:

1. examine the effect of extreme heat days (EXHD) on current health spending as a percentage of GDP
2. assess the impact of diurnal temperature range (DTR) on current health expenditure relative to GDP (CENGDP).

1.2 **Hypotheses**

H_{o1}: There is no significant positive correlation between extreme heat days and the percentage of GDP allocated to healthcare spending.

H_{o2}: The diurnal temperature range does not have a significant effect on current health expenditure as a proportion of GDP.

2. LITERATURE REVIEW

2.1 Conceptual Review

2.1.1 Understanding Extreme Heat

Anthropogenic greenhouse gas emissions are fundamentally altering Earth's climate systems, resulting in persistent changes to global temperature distributions. One of the most visible consequences of this phenomenon is the increased occurrence, intensity, and longevity of heatwaves, which pose substantial risks to public health, ecosystems, and critical infrastructure (IPCC, 2021). Mitigating the adverse effects of extreme heat requires both emission reductions and adaptive strategies such as climate-responsive architecture, urban greening, and comprehensive heat action frameworks (Anderson et al., 2022).

2.1.2 Key Components of Extreme Heat:

i **Greenhouse Gases (GHGs):** GHGs such as carbon dioxide, methane, and nitrous oxide contribute to the greenhouse effect by trapping solar heat in the Earth's atmosphere—a natural process essential for sustaining life (NASA, 2023).

ii **Anthropogenic Influence:** Industrial activities, notably the combustion of fossil fuels and widespread deforestation, have escalated atmospheric GHG concentrations, intensifying the greenhouse effect (Rogelj et al., 2018).

iii **Global Warming:** The cumulative impact of these emissions has driven a gradual increase in global mean temperatures, commonly referred to as global warming.

2.1.3 Mechanisms Linking Global Warming and Extreme Heat:

i **Shifts in Temperature Distribution:** Global warming alters the statistical distribution of daily temperatures, shifting the mean toward higher values. Consequently, the frequency and extremity of high-temperature days increase (Diffenbaugh & Scherer, 2011).

ii **Temperature Extremes:** As the upper tail of the distribution extends, record-breaking heat becomes more likely.

2.1.4 Amplifying Variables

i **Atmospheric Patterns:** Climate change influences wind currents and jet streams, promoting persistent high-pressure systems that trap heat, forming so-called "heat domes" (Meehl & Tebaldi, 2004).

ii **Soil Moisture Depletion:** Elevated temperatures cause greater evapotranspiration, drying soils. Dry ground absorbs heat faster than moist soil, exacerbating surface temperatures (Seneviratne et al., 2010).

iii **Urban Heat Island (UHI) Effect:** Urban areas retain more heat due to their infrastructure, making cities significantly warmer than rural surroundings. Climate change exacerbates this disparity (Oke, 1982).

iv **Feedback Mechanisms:** Melting snow and ice reduce surface albedo, thereby increasing solar absorption and accelerating warming (Flanner et al., 2011).

v **Intensified Heat Events:** The interaction of these factors results in more frequent, more intense, and longer-duration heatwaves globally (Perkins-Kirkpatrick & Lewis, 2020).

2.1.5 Consequences of Extreme Heat:

i **Public Health:** Heat-related illnesses include heat exhaustion, heatstroke, dehydration, and worsened cardiovascular and respiratory ailments. Vulnerable groups—such as children, the elderly, outdoor workers, and individuals with chronic illnesses—face disproportionate risks (Watts et al., 2023).

ii **Agriculture and Food Security:** Crop failure, livestock stress, and reduced agricultural productivity are significant threats (Lobell et al., 2011).

iii **Ecological Impacts:** Heatwaves contribute to biodiversity loss, increased wildfire risk, and altered reproductive cycles in flora and fauna (Pachauri et al., 2014).

iv **Infrastructure:** Heat-induced energy surges strain electricity grids, damage transportation systems, and compromise essential public services.

v **Water Availability:** Elevated evaporation rates and reduced water supply pose challenges for water management and intersectoral competition (Kundzewicz et al., 2007).

2.1.6 The Intersection of Heat and Human Health

Exposure to extreme heat is one of the most pressing environmental and occupational health threats of the modern era. It significantly elevates the risk of mortality and exacerbates existing medical conditions, including cardiovascular disease, asthma, diabetes, and psychological disoCENGDPrs. Additionally, it may increase accident rates and facilitate the spread of infectious diseases (Basu, 2009). The buCENGDPn of heat exposure has intensified globally. Between 2000–2004 and 2017–2021, mortality due to extreme heat among individuals aged 65 and older increased by roughly 85% (Watts et al., 2023). Zhao et al. (2021) estimate that from 2000 to 2019, approximately 489,000 deaths occurred annually due to heat, with Asia and Europe bearing 45% and 36% of the toll respectively. Europe alone recoCENGDPd an estimated 61,672 excess deaths from heat in the summer of 2022. Historically, catastrophic events such as the 2003 European heatwave and Russia’s 2010 heatwave underscore the lethal potential of prolonged heat exposure, with fatalities reaching 70,000 and 56,000 respectively.

Susceptibility to heat-related health outcomes is shaped by both biological factors (such as age and chronic illness) and external factors (like occupational exposure, income level, and housing quality). Yet, most adverse outcomes are preventable through targeted policies, effective public health messaging, and cross-sectoral planning (WHO, 2021). The World Health Organization has issued frameworks for anticipating and managing heat-related risks, stressing the importance of integrating heat risk reduction into health systems and climate strategies.

2.1.7 Pathways through Which Heat Affects Health

The human thermoregulatory system struggles under persistent heat stress, especially when aggravated by high humidity, stagnant airflows, and intense solar radiation. When the body cannot effectively dissipate heat, individuals become vulnerable to heat exhaustion and potentially fatal heatstroke (Bouchama & Knochel, 2002). The stress on internal systems, particularly cardiovascular and renal functions, intensifies in those with pre-existing medical conditions. Moreover, extreme heat can undermine the functionality of health infrastructure. Heat-related power outages, transport system failures, and limited access to medical care exacerbate health risks during heatwaves. In occupational contexts, high temperatures reduce productivity and elevate injury risks, while also disrupting educational and institutional routines. Additionally, heat events often coincide with poor air quality—particularly elevated ground-level ozone—which further compounds respiratory challenges (Kinney, 2008).
The severity of health impacts from extreme heat depends on the magnitude and duration of heat events, the degree of acclimatization among the local population, and the robustness of community infrastructure and emergency response mechanisms.

2.2 Theoretical Review

This study, titled *"The Financial BuCENGDPn of Climate Change: Accounting for Extreme Heat and Health Expenditures,"* is grounded in a multidisciplinary theoretical foundation that integrates concepts from environmental health, health economics, climate change economics, and public health models. These frameworks collectively facilitate an understanding of how extreme heat, as a climate-related hazard, contributes to escalating healthcare costs and broader economic repercussions.

2.2.1 Environmental Health Theory

Environmental health theory emphasizes the impact of environmental exposures—such as extreme temperatures—on human health. This theoretical lens suggests that excessive heat exposure can intensify pre-existing medical conditions and precipitate acute health crises like heatstroke, dehydration, and cardiorespiratory disoCENGDPrs. Vulnerable populations, including the elderly, young children, and individuals with chronic illnesses, are particularly susceptible to such effects (Schwartz et al., 2021). As these health complications rise during heatwaves, so too does the demand for medical services and emergency care.

2.2.2 Health Economics Theory

Health economics theory provides insights into the ways health outcomes affect and are affected by economic variables. This perspective posits that increased exposure to extreme heat can lead to higher incidences of illness and injury, thereby inflating both direct healthcare expenditures (e.g., hospitalization, emergency care, medication) and indirect costs (e.g., absenteeism, decreased productivity, and long-term disability). As heat-related morbidity and mortality increase, the pressure on public and private healthcare systems becomes more pronounced, especially in regions with inadequate climate adaptation (Zivin & Neidell, 2014).

2.2.3 Climate Change Economics

This theoretical framework evaluates the economic implications of climate change, particularly the costs associated with adaptation, mitigation, and climate-related damage. In the context of extreme heat, climate change economics predicts escalating financial buCENGDPns on governments, communities, and individuals. These costs arise not only from increased healthcare spending but also from losses in labor productivity, higher insurance claims, infrastructural strain, and mortality (Stern, 2007). The theory underscores the urgency of climate resilience investments to reduce long-term socioeconomic disruptions.

2.2.4 BuCENGDPn of Disease Framework

The buCENGDPn of disease framework is a public health model used to quantify the overall impact of diseases and health conditions on populations. It often uses metrics such as disability-adjusted life years (DALYs) and quality-adjusted life years (QALYs) to capture both mortality and morbidity effects. Applied to this study, the framework measures the cumulative health toll of heat-related illnesses, providing a clearer picture of how heatwaves affect population health and healthcare systems (Murray & Lopez, 2013). It also informs resource allocation and health policy decisions.

2.2.5 Cost of Illness (COI) Model

The cost of illness model is an economic tool used to estimate the financial costs attributable to specific health conditions. It distinguishes between direct medical expenses (e.g., treatment, diagnostics, pharmaceuticals) and indirect costs (e.g., lost income, reduced work capacity, and informal caregiving). By applying the COI model to heat-induced health outcomes, this study estimates the total economic buCENGDPn borne by individuals, healthcare institutions, and society at large during extreme heat events (Rice et al., 2022).

2.2.6 Social Determinants of Health (SDH) Theory

The SDH theory examines how socioeconomic and environmental conditions influence health outcomes and disparities. Factors such as income, education, housing quality, and access to healthcare shape a population's vulnerability to environmental hazards like extreme heat. This framework helps explain why socially and economically marginalized groups are more likely to suffer adverse health effects during heatwaves, thereby incurring greater health and economic buCENGDPns (Marmot et al., 2008). Integrating SDH into the analysis supports the formulation of equitable, inclusive climate-health policies..

2.3 Empirical Review

Liu et al. (2019), in their case-crossover study conducted in Jinan, China, examined the association between extreme heat and hospital admissions among patients with mental illness from 2010 onwards. Utilizing multifactor logistic regression while accounting for time trends and seasonal variations, the researchers found that prolonged daily maximum temperatures (≥35°C for ≥3 days) significantly increased hospital admission rates in this vulnerable group.

Phung et al. (2017) conducted a multi-province time-series meta-analysis in Vietnam, analyzing data from 2002 to 2015. The study assessed the effect of apparent temperatures (≥90th percentile for ≥3 consecutive days) on hospital admissions. Applying a Generalized Linear Model (GLM) with Poisson distribution and Distributed Lag Models (DLM), the researchers identified a significant positive relationship between elevated temperatures and hospital admissions across both northern and southern cities, with stronger effects during summer.

Sun et al. (2014) investigated the impact of extreme heat on emergency department visits (EDV) and emergency admissions (EAD) in Pudong New Area, China. Conducted between 2011 and 2013, this time-series analysis utilized Poisson regression with Generalized Additive Models (GAM). The study found that daily mean temperatures at the 90th, 95th, and 99th percentiles significantly elevated EDV and EAD, emphasizing seasonal and calendar effects.

Dang et al. (2019) performed a time-series analysis in Ho Chi Minh City, Vietnam, from 2010 to 2013, evaluating hospital admissions under conditions where daily average temperatures exceeded the 97th percentile for at least two consecutive days. The researchers used quasi-

Poisson regression with Distributed Lag Nonlinear Models (DLNM) and found a strong link between high temperatures and increased hospital visits, moderated by seasonal trends.

Cheng et al. (2016) employed a time-series approach in Huainan, China (2011–2013), examining the effects of heat exposure—defined by 95th to 99th percentile daily mean temperatures sustained for at least two days—on emergency admissions. Utilizing quasi-Poisson regression with DLNM, they controlled for public holidays, day of the week, and relative humidity (RH). The study confirmed the detrimental health impact of extreme heat.

Phung et al. (2016), in another study from Ho Chi Minh City, Vietnam (2004–2013), focused on the effects of extreme temperatures (≥99th percentile for ≥2 days) on hospital admissions. Using GAM and DLNM with Poisson regression, their findings supported a robust association between high temperatures and increased hospitalizations, influenced by relative humidity and temporal factors.

Trang et al. (2016) investigated the effects of high temperatures on mental health hospitalizations in Hanoi, Vietnam, between 2008 and 2012. Using binomial time-series regression, they found that daily maximum temperatures at or above the 90th percentile (exceeding 35°C for 3–7 consecutive days) led to significant increases in admissions among patients with mental disoCENGDPrs, particularly under conditions of seasonality and weekly patterns.

Zhang et al. (2019) conducted a time-stratified case-crossover study in Changnan, China (2010–2012), analyzing the impact of heatwaves (daily maximum temperature >35°C for ≥3 consecutive days) on outpatient visits. Using conditional Poisson regression, they accounted for various environmental covariates (e.g., RH, air pollutants, sunshine hours) and confirmed a strong association between heat and outpatient service use.

Chu et al. (2022) analyzed data from 14 provinces in Vietnam (2003–2015) using a case-crossover design. The study assessed hospital admissions following days when maximum temperatures were ≥95th percentile. Conditional logistic regression revealed increased hospital admissions due to extreme heat, moderated by seasonality and RH.

Li et al. (2017) examined the effects of sustained high average temperatures (above threshold values for ≥3 days) on hospital admissions in Chongqing, China (2009–2013). Applying zero-inflated Poisson regression, their findings indicated a significant rise in admissions, especially when controlling for RH and day-of-week effects.

Zhao et al. (2019) carried out a time-series study in five Brazilian regions (2000–2015), linking hospital admissions to multi-day high mean temperatures (90th–97.5th percentiles). Using quasi-Poisson regression with DLM, the study found temperature-induced hospitalizations were significantly moderated by RH, holidays, and long-term climate trends.

Huang et al. (2023) conducted a time-stratified case-crossover study across 23 areas in China (2014–2019). They analyzed healthcare expenditures and hospital admissions linked to daily mean temperatures above the 90th, 95th, and 97.5th percentiles over 2–4 days. Utilizing DLNM with conditional quasi-Poisson regression, they identified heat-related increases in both health costs and hospital utilization, influenced by RH and public holidays.

Song et al. (2018) studied the health effects of extreme heat in Haidian District, Beijing (2009–2012), using time-series analysis. The study applied GLM with quasi-Poisson regression and DLNM and found that daily mean temperatures above the 95th percentile were associated with significant increases in EDV, further influenced by air pollutants and seasonal variations.

Van der Linden et al. (2019) performed a time-series threshold regression study in Karachi, Pakistan (2009–2016), using the Excess Heat Index (EHI) as the key exposure metric. The study found a strong link between EHI-defined heatwaves and emergency department visits, influenced by weekly patterns and seasonal fluctuations.

Kakkad et al. (2014) focused on neonatal and infant hospitalizations in Ahmedabad, India (2009–2011). Using GLM with Poisson regression, they assessed the effects of extreme heat—defined as temperatures >45°C or >4°C above normal. The study found that neonates and infants were highly susceptible to temperature spikes, with hospitalizations rising in response to elevated heat levels.

Hu et al. (2020) conducted a time-series study in Shenzhen, China (2013–2017), linking health outcomes to mean temperatures exceeding the 75th to 99th percentiles over 2–4 days. The DLNM with quasi-Poisson distribution confirmed increased EADs during heatwave periods, influenced by pollutants, holidays, and temporal trends.

Oray et al. (2018), in a cross-sectional study in Izmir, Turkey (June 2016), explored the effect of higher-than-average seasonal temperatures on emergency department visits and mortality. Using Kolmogorov-Smirnov, t-tests, and chi-square methods, they found statistically significant increases in ED usage and mortality during the study period.

Mohammadi et al. (2019) investigated preterm birth (PTB) and hospital admission trends in Sabzevar, Iran (2011–2017), under elevated temperatures (>90th percentile for ≥2 days). Applying GAM with quasi-Poisson regression and DLNM, the researchers confirmed that extreme heat increased PTB risk and health service utilization, influenced by pollution and rainfall.

Nhung et al. (2023) used time-series data (2010–2018) from southern Vietnam to assess the effect of maximum temperature (≥90th percentile for ≥3 days) on hospital admissions. Employing quasi-Poisson regression with time and humidity adjustments, they reported a strong correlation between heat events and increased hospitalization.

Kim, Miao, and Zhu (2025), in their study on the impact of extreme temperatures on hospital utilization and public health insurance spending in the United States, utilized nationwide county-level panel data. Employing a fixed effects model, they estimated the effects of annual variations in the number of hot and cold days on hospital admissions and medical reimbursements for low-income and elderly beneficiaries. The findings revealed that extreme heat notably increased hospital admissions and inpatient days, particularly among Medicaid and Medicare patients. The study underscores the fiscal implications of climate-induced health risks on public health insurance programs .

Zhang et al. (2024) conducted a time-series analysis in Guangzhou, China, to assess the association between extreme heat and outpatient visits for mental disoCENGDPrs. Utilizing a quasi-Poisson generalized linear model, the study found that heatwaves significantly elevated the number of outpatient visits for mental health conditions, including schizophrenia, mood disoCENGDPrs, and neurotic disoCENGDPrs. The research highlights the mental health challenges posed by rising temperatures in urban settings .

Schmeltz, Petkova, and Gamble (2016) explored the economic buCENGDPn of hospitalizations for heat-related illnesses in the United States from 2001 to 2010. Analyzing data from the Nationwide Inpatient Sample, they reported that healthcare costs for heat-related hospitalizations were disproportionately higher among low-income individuals and certain racial/ethnic minorities. The study emphasizes the health inequities exacerbated by extreme heat events and the need for targeted public health interventions .

Huang et al. (2021) investigated the relationship between ambient temperatures and the costs associated with emergency department visits (EDVs) across 17 sites in China from 2014 to 2018. Applying a quasi-Poisson generalized additive regression with a distributed lag nonlinear model, the study found that extreme heat increased both examination and medication costs in emergency settings. Notably, individuals aged 18–44 and those with genitourinary diseases were more susceptible to heat-related cost increases. The research quantifies the economic impact of temperature extremes on healthcare systems .

Limaye et al. (2019) estimated the economic costs associated with health outcomes due to suboptimal ambient temperature exposures in the Minneapolis/St. Paul metropolitan area. Utilizing a distributed lag nonlinear model, they assessed mortality, emergency department visits, and hospitalizations across various temperature levels. The study concluded that both extremely low and high temperatures led to substantial economic costs, amounting to approximately $2.7 billion annually, highlighting the financial implications of temperature-related health risks .

2.3.1 Critique of the Empirical Studies

Despite a growing body of empirical research linking extreme heat to adverse health outcomes, current studies display several notable limitations. First, there exists a geographical concentration bias, with the majority of research conducted in East and Southeast Asia—particularly in China and Vietnam. This regional focus restricts the generalizability of findings to other climatically vulnerable but underrepresented areas such as sub-Saharan Africa and parts of the Middle East.

Secondly, there is a lack of focus on vulnerable subpopulations. Most studies aggregate data at the population level, overlooking groups at heightened risk—such as the elderly, low-income earners, outdoor laborers, or individuals with chronic illnesses. Only a limited number, like Kakkad et al. (2014) on neonates and Trang et al. (2016) on mental health patients, have explicitly investigated these subgroups. Thirdly, many analyses exhibit a limited integration of socioeconomic and behavioral factors. Although meteorological and temporal variables are routinely controlled for, variables such as income level, housing quality, public awareness, and access to adaptive infrastructure (e.g., cooling systems) are often excluded, despite their potential to mediate or moderate health outcomes. In addition, there is a tendency toward outcome homogeneity, with most studies focusing narrowly on hospital admissions and emergency department visits. This overlooks broader consequences such as long-term morbidity, reduced economic productivity, and psychosocial effects—factors critical to holistic public health assessments.

Lastly, the methodological similarity across studies—often involving Poisson regression models coupled with distributed lag non-linear models (DLNM) or generalized additive models (GAM)—may constrain innovation and obscure more complex causal or lagged dynamics. Many analyses also adopt threshold-based metrics without exploring cumulative exposure effects. Consequently, while prior studies have laid foundational knowledge of heat-health linkages, few have quantified the financial implications of extreme heat, particularly in climate-vulnerable yet data-sparse regions. This study seeks to fill that gap by examining how climate-induced temperature extremes translate into tangible economic buCENGDPns on individuals and health systems—thereby advancing the understanding of climate change's fiscal dimensions in public health.

3. MATERIAL AND METHODS

The study adopted an ex post facto research design from 2000 to 2023. Secondary data collected from the World Bank was analyzed using descriptive statistics, correlation, and regression analysis. The dependent variable, health expenditure, was proxied by Current Health Expenditure per Capita (Current US$) for Nigeria (natural logarithm of cost) and Current Health Expenditure (% of GDP). The independent variables include: extreme heat days (number of heat days divided by 365/6, then multiply the result by 100) and diurnal temperature range (the difference between the daily maximum and minimum temperatures) (Dummy variable: 0 if no difference between daily maximum and minimum temperatures, and 1 if a difference was experienced).

To estimate the model and examine the proposed hypotheses, the following regression models were estimated:

CENGDP=f (EXHD, DTR, POP)…Eqn 1

The model is explicitly stated as follows:

CENGDPIit=α0+β1EXHDit+β2DTRit+β3POPit+ϵ…Eqn 2

Where:

i CENGDP: Current health expenditure as a percentage of GDP

ii EXHD: Extreme heat days

iii DTR: Diurnal temperature range

iv POP: Population of a country

v β1, β2, β3: Coefficients of the explanatory variables

vi i: Denotes the number of countries in the panel

vii t: Denotes the time period of the panel data

viii ε: Error term

4. RESULT AND DISCUSSIONS

4.1 Data Analysis

4.1 Descriptive Statistics

4.1.1 Descriptive Analysis of Data

Descriptive statistics were used to evaluate the characteristics of the data, including the mean, maximum, minimum, standard deviation, and to check for the normality of variables. To assess for multicollinearity, variance inflation factor (VIF) analysis was conducted to confirm the results of multicollinearity. Multiple regression analysis was then employed to evaluate the effect of the independent variables on the dependent variable and predict the degree of effect the independent variables have on the dependent variable. The alternate hypothesis was accepted if the p-value was less than 0.05; otherwise, the null hypothesis was rejected.

Table 1: Descriptive statistics of dependent, independent, and control variables

	CENGDP	EXHD	DTR	POP
Mean	2.34E+08	8.99E+07	0.307	1.44E+08
Median	1.13E+08	8.07E+06	0.000	6.11E+07
Maximum	1.63E+09	1.01E+09	1.000	9.96E+08
Minimum	1.00E+07	0.000	0.000	1.00E+07
Std. Dev.	2.80E+08	1.91E+08	0.462	2.01E+08

Skewness	1.976	2.847	0.837	2.294
Kurtosis	7.105	10.978	1.701	7.806
Jarque-Bera	564.222	1669.241	78.031	766.937
Probability	0.000	0.000	0.000	0.000

Source: E-Views 11, 2025

Key: CENGDP = Current health expenditure as a percentage of GDP; EXHD = Extreme heat days; DTR = Diurnal temperature range and POP = Population of a country

The mean value of *Current Health Expenditure as a Percentage of GDP (CENGDP)* is 2.34E+08, while the median is 1.13E+08. The relatively high mean and substantial standard deviation (2.80E+08) indicate considerable variation in expenditure across countries. This variability suggests that in years with higher incidences of extreme heat, government spending on health tends to increase significantly. The positive skewness (1.976) and high kurtosis (7.105) further imply that a small number of observations (likely corresponding to extreme heat years) are characterized by exceptionally high government health expenditures, suggesting that extreme heat has a significant impact on public health spending.

Extreme Heat Days (EXHD) reflect the extent to which governments face climate-related stress and potentially invest in mitigating the effects on public health. The mean value of EXHD is 89,975,263, while the median is only 8,074,000. This large gap, combined with a high standard deviation (1.91E+08), suggests a highly unequal distribution. Most countries have relatively few extreme heat days or limited government response, while a few countries are heavily affected and possibly investing more in heat mitigation strategies. The positive skewness (2.847) and kurtosis (10.978) reinforce the notion that only a few countries experience exceptionally high values, either due to climatic conditions or proactive adaptation practices.

Diurnal Temperature Range (DTR) captures whether governments have adopted environmental practices related to daily temperature fluctuations. The mean DTR value is 0.307, with a median of 0.00, indicating that, on average, there is moderate implementation of such practices, but many governments show no or minimal adoption. The standard deviation (0.462) is relatively high considering the 0–1 range, which reflects substantial variability. The positive skewness (0.837) suggests that while implementation is generally low, there is a growing number of governments engaging in such practices—possibly due to increasing climate pressure or global awareness.

The *Population of a Country (POP)* exhibits a mean of 1.44E+08 and a median of 61,121,470, with a standard deviation of 2.01E+08. This indicates substantial variation in country sizes. The positive skewness (2.294) and high kurtosis (7.806) imply that a small number of highly populous countries significantly influence the distribution. Most countries have comparatively smaller populations, but the presence of a few large nations skews the average upward—confirming a right-skewed population distribution.

In summary, the frequency distribution of current health expenditures is concentrated in the lower range, particularly between 0 and 200,000,000. This suggests that the majority of governments allocate modest resources to health expenditures, with only a few committing substantial investments. The skewness and kurtosis metrics corroborate this, indicating that strategic focus on health expenditures is more prominent among a small subset of countries. These outliers could reflect governments with greater fiscal capacity, heightened exposure to climate risks, or stronger health infrastructure commitments.

Table 2 Correlation analysis of dependent, independent and control variable

	CENGDP	EXHD	DTR	POP
CENGDP	1.0000			
EXHD	0.6962	1.0000		
DTR	0.0180	0.0978	1.0000	
POP	0.7303	0.0181	-0.0679	1.0000

Source: E-Views 11

Key: CENGDPI- Current health expenditure as a percentage of GDP Expenditures; EXHD extreme heat days; DTR- Diurnal temperature range; pop -Population of a country.

The provided the Pearson correlation coefficient matrix of the variables. The coefficients range from -1 to 1, indicating the strength and direction of the linear relationship between the variables. Current health expenditure positively correlated with extreme heat 0.6962; suggesting that Current health expenditure also tend to invest more in extreme heat.

4.2 Test of Hypotheses

Table 3 Regression Analysis Result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.270322	0.167351	1.615293	0.1073
EXHD	0.361629	0.015356	23.54904	0.0000
DTR	-0.005888	0.058474	-0.100694	0.9199
POP	0.663179	0.024912	26.62132	0.0000

4.2.1 Hypothesis One

H_{01}: There is a significant positive relationship between extreme heat days and current health expenditure as a percentage of GDP.

Based on the results in Table 3**,** the t-statistic for *Extreme Heat Days (EXHD)* is 23.54904**,** indicating a highly significant positive effect on current health expenditure. This suggests that an increase in extreme heat days is strongly associated with higher government spending on health, likely due to rising heat-related health burdens. The p-value **of** 0.0000**,** being less than the 0.05 significance level, confirms the statistical significance of this relationship. Consequently, the null hypothesis is rejected**,** and the alternative hypothesis is accepted**:** extreme heat days significantly influence current health expenditure.

This finding implies that governments tend to increase health spending in response to the growing health challenges posed by extreme heat events. However, the observation that this spending may still fall short of optimal levels may suggest that many governments do not sufficiently prioritize climate-related health adaptation in their policy agenda.

Supporting this conclusion**,** Zhang et al. (2019) conducted a time-stratified case-crossover study in Changnan, China (2010–2012) and found that heatwaves (defined as maximum daily temperatures above 35°C for three or more consecutive days) were significantly associated with increased outpatient visits. Similarly, Chu et al. (2022) analyzed data from 14 Vietnamese provinces (2003–2015) and confirmed, through conditional logistic regression, a surge in hospital admissions following extreme heat days—an effect moderated by seasonality and relative humidity (RH).

4.2.2 **Hypothesis Two**

H_{02}**:** Diurnal temperature range does not significantly influence current health expenditure as a percentage of GDP.

From Table 3**,** the t-statistic for *Diurnal Temperature Range (DTR)* is -0.100694**,** indicating a very weak and insignificant negative effect on current health expenditure. The p-value **of** 0.0000 appears contradictory, as such a value typically suggests statistical significance. However, if the correct p-value is indeed greater than 0.05 (as the interpretation states), the result is not statistically significant**,** and thus the null hypothesis is accepted**:** DTR does not significantly affect current health expenditure. This result implies that variations in diurnal temperature range may not directly impact government health spending, possibly because such changes are less immediately disruptive than prolonged heatwaves or extreme heat events.

Nonetheless, other studies have shown that broader temperature-related stress can influence health system demands. For instance, Li et al. (2017)**,** using zero-inflated Poisson regression in Chongqing, China (2009–2013), found that sustained high temperatures significantly increased hospital admissions. Similarly, Zhao et al. (2019) reported significant temperature-induced hospitalizations in Brazil (2000–2015), moderated by relative humidity, holidays, and long-term climate patterns. Furthermore, Huang et al. (2023) analyzed data from 23 Chinese cities (2014–2019) and found that higher daily mean temperatures over multiple days significantly increased healthcare expenditures and hospital utilization, using distributed lag nonlinear models (DLNM).

5. CONCLUSION AND RECOMMENDATIONS

This study investigated the impact of climate-related variables—specifically, *Extreme Heat Days* and *Diurnal Temperature Range*—on current health expenditure as a percentage of GDP, using panel data analysis across multiple countries. The findings demonstrate a statistically significant and positive relationship between extreme heat days and government health expenditure. This supports the assertion that climate-induced heat stress places increased demand on public health systems, compelling governments to allocate more resources to address the resulting health challenges. In contrast, diurnal temperature range showed no significant effect on current health spending, indicating that daily temperature variations may not be perceived as urgent or critical triggers for public health investment.

The analysis also revealed substantial variability in both climate indicators and health expenditure across countries, with right-skewed distributions suggesting that a few nations experience the most extreme conditions and respond with comparatively larger investments. However, the overall pattern suggests that **many governments still underinvest** in climate-resilient health systems, particularly in the face of rising global temperatures.

1. Governments, especially in heat-prone regions, should prioritize allocating more resources to strengthen health systems against climate-induced pressures. This includes scaling up emergency response units, expanding public health infrastructure, and investing in heat mitigation technologies.

2. National health policies should explicitly incorporate climate resilience planning, including mechanisms for monitoring extreme heat and its impact on public health. Multi-sectoral collaborations between meteorological agencies, ministries of health, and urban planning bodies are essential.

3. Governments should establish early warning systems for heatwaves and educate the public on preventive health measures during extreme weather events. These systems are vital in reducing hospital admissions and overall health system burdens.

4. International bodies and donor agencies should support low- and middle-income countries in building adaptive health infrastructure. Technical and financial support can bridge gaps in capacity and ensure equitable climate adaptation across nations.

5. Continued research is needed to evaluate the long-term economic burden of climate-induced health issues. Governments should support data collection systems that enable real-time analysis of climate-health relationships to guide evidence-based policymaking.

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