PROCEEDINGS OF THE INTERNATIONAL CONFERENCE FOR INSTITUTE OF ADMINISTRATION (ICIA 2025)

AHMADU BELLO UNIVERSITY ZARIA - NIGERIA

Website: *https://icia.org.ng* **ISBN:** *978-978-695-265-9* ***Volume I, 2025***

CLIMATE CHANGE, HEALTH SPENDING, AND MATERNAL MORTALITY IN EMERGING AFRICAN ECONOMIES: SDG POLICY IMPLICATIONS

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ABSTRACT

Climate change has emerged as a major threat to sustainable development, particularly in low- and middle-income countries where adaptive capacity is limited. This study examines the combined effects of climate-related stress and public health investment on health outcomes relevant to the Sustainable Development Goals (SDGs) in seven emerging African economies, namely Egypt, Ethiopia, Ghana, Kenya, Nigeria, Senegal, and South Africa, over the period 2000 to 2021. Using panel data econometric techniques, including Pooled OLS, Fixed Effects, and Random Effects models, the study assesses how changes in climate conditions and government health expenditure influence maternal health outcomes, a key component of SDG 3. Results indicate that climate change exerts a statistically significant and adverse effect on maternal health, while higher public spending on health services significantly mitigates this impact. These findings underscore the need for integrated policies that link climate resilience with healthcare financing. The study recommends that African policymakers enhance investment in climate-adaptive health infrastructure and increase targeted maternal health spending as part of broader sustainable development strategies.

Keywords: *Climate change, sustainable development, public health expenditure, and maternal health*

1. Introduction

Maternal mortality remains a pressing global health challenge, particularly in low- and middle-income countries (LMICs). Despite some progress over the past two decades, sub-Saharan Africa still accounts for approximately two-thirds of global maternal deaths, with an estimated maternal mortality ratio (MMR) of 545 deaths per 100,000 live births in 2020-well above the Sustainable Development Goal (SDG) target of less than 70 by 2030 (WHO, 2022). In many emerging African economies, maternal mortality is not only a health indicator but a reflection of broader systemic inequities related to health financing, service delivery, infrastructure, and environmental stressors. Among the least explored dimensions of maternal mortality in Africa is the role of climate change, particularly rising temperatures and weather variability, in shaping maternal health outcomes. A growing body of evidence links extreme heat exposure to negative pregnancy outcomes, such as increased risk of preterm birth, low birth weight, hypertensive disorders, and maternal death (Chersich et al., 2020; Kuehn & McCormick, 2017). Climate stress—manifesting through extreme heat, droughts, or flooding, can further undermine agricultural productivity and livelihoods, delay access to care, and intensify the burden on already fragile health systems (van Zutphen et al., 2021). Despite this, empirical research quantifying the causal effect of climate variables on maternal mortality remains limited, particularly in African contexts where health systems are underfunded and vulnerable populations are highly exposed.

Public health spending is widely recognized as a key determinant of health outcomes, including maternal mortality. Increased government health expenditure (GHE) has been associated with reductions in maternal and child mortality, improved service coverage, and greater financial risk protection (Novignon & Lawanson, 2017; Barenberg et al., 2017). However, health financing in sub-Saharan Africa continues to fall short of the Abuja Declaration's target of allocating at least 15% of national budgets to the health sector (WHO, 2016). Many African countries still rely heavily on out-of-pocket payments and external aid, with wide disparities in per capita spending and institutional capacity (WHO, 2017; Kiross et al., 2020). There is, therefore, a need to empirically assess the extent to which domestic health spending moderates or mediates the relationship between environmental stressors and maternal mortality.

Against this backdrop, the present study investigates the joint and independent effects of climate change (proxied by temperature) and government health spending on maternal mortality in a panel of seven emerging African economies, Egypt, Ethiopia, Ghana, Kenya, Nigeria, Senegal, and South Africa, spanning the period 2000 to 2021. These countries were selected based on regional diversity, availability of data, and their varying levels of vulnerability to climate change and institutional capacity in health governance. By integrating insights from environmental economics, public health finance, and development studies, this study aims to fill an important gap in both academic and policy-oriented literature.

The paper contributes to the empirical literature in several ways. First, it provides one of the few panel-data analyses examining maternal mortality as a health outcome associated with climate change in Africa. Second, it empirically assesses the role of government health expenditure alongside climate variables, highlighting the importance of public health investment in shaping maternal health outcomes in climate-vulnerable settings. Third, the study situates its findings within the broader Sustainable Development Goals (SDGs) framework-particularly SDG 3 (Good Health and Well-being) and SDG 13 (Climate Action)-thereby offering timely and policy-relevant insights for African governments and development partners.

The rest of the paper is structured as follows. Section 2 reviews the theoretical and empirical literature on climate change, health spending, and maternal mortality. Section 3 outlines the data sources and empirical methodology. Section 4 presents the estimation results. Section 5 discusses the results, while Section 6 concludes the paper.

2. Literature Review

2.1 Theoretical Literature

Understanding the nexus between climate change, health spending, and maternal mortality requires a multidisciplinary theoretical framework that integrates concepts from public health economics, human capital theory, and ecological vulnerability. At the core of this discussion lies Grossman's Human Capital Model (Grossman, 1972), which posits health as both a consumption and investment good. Health investments, such as public spending on maternal services, are expected to increase productivity, enhance wellbeing, and reduce mortality. Within this framework,

maternal health outcomes are influenced by access to prenatal care, skilled birth attendance, emergency obstetric services, and postnatal care, all of which are contingent upon the level and efficiency of health expenditure (Barenberg, Basu & Soylu, 2017; Novignon & Lawanson, 2017).

Expanding on this, the Health Production Function model (Fayissa & Gutema, 2005) views maternal mortality as an output that depends on several inputs, including government health expenditure, education, sanitation, and environmental factors such as climate. When health spending is sufficient, it facilitates the provision of critical infrastructure, medical personnel, pharmaceuticals, and public health education, all of which contribute to reduced maternal mortality (Arthur & Oaikhenan, 2017; Barroy et al., 2016). However, disparities in fiscal space and budget allocation efficiency across African economies often limit the potential of health spending to fully translate into better maternal health outcomes. From a climate perspective, the Vulnerability and Adaptation Framework (IPCC, 2014) provides a useful lens for examining how climatic stressors exacerbate maternal mortality risks. Rising temperatures, extreme weather events, and shifting disease ecologies (e.g., malaria or cholera outbreaks) can disrupt access to maternal health services, increase the incidence of pregnancy-related complications, and heighten vulnerability in already marginalized populations (Ebi & Semenza, 2008; Kiross et al., 2020). The framework emphasizes the interaction between exposure, sensitivity, and adaptive capacity. In many emerging African economies, adaptive capacity remains weak due to underfunded health systems, fragile infrastructure, and limited early warning systems.

Bringing both strands together, the Sustainable Livelihoods Framework (Chambers & Conway, 1992) offers a holistic approach, suggesting that climate resilience and health security are mutually reinforcing components of sustainable development. It highlights how environmental shocks (such as droughts or floods) erode household assets and income, reducing access to healthcare and worsening maternal outcomes. In this sense, public health spending can serve as a form of climate adaptation by strengthening system resilience and buffer capacities in vulnerable communities. Therefore, the intersection of these theoretical perspectives implies that maternal mortality in Africa is a function of not just socioeconomic determinants or healthcare access, but also environmental stressors and institutional responses. The integration of climate action into health

financing strategies is not only a policy imperative but also a theoretical necessity for achieving SDG 3 (Good Health and Well-being) and SDG 13 (Climate Action).

2.2 Empirical Literature

Climate Change and Maternal Mortality

Climate change is increasingly recognized as a significant indirect determinant of maternal health, particularly in low- and middle-income countries where health systems are often fragile and environmental shocks are more acute. Rising ambient temperatures, changing rainfall patterns, and increased frequency of climate-related disasters, such as floods and droughts, can adversely impact maternal health outcomes by straining healthcare infrastructure, disrupting service delivery, and exacerbating existing vulnerabilities (Kuruppu & Willie, 2015; Sorensen et al., 2018).

One of the principal mechanisms linking climate change to maternal mortality is heat stress. Elevated temperatures have been associated with increased risks of pregnancy complications, including preterm birth, low birth weight, and hypertensive disorders, all of which can contribute to higher maternal mortality rates (Chersich et al., 2020). For example, studies in sub-Saharan Africa have shown that women exposed to high heat during pregnancy experience higher rates of complications and reduced access to prenatal care due to climate-related transport and service disruptions (Grace et al., 2015). Moreover, climate-induced food insecurity has a critical bearing on maternal nutrition, which in turn affects pregnancy outcomes. Droughts and floods, both exacerbated by climate change, can reduce agricultural productivity and escalate food prices, increasing the prevalence of maternal malnutrition, anemia, and micronutrient deficiencies (Lloyd et al., 2011). These deficiencies elevate the risk of hemorrhage, infection, and other complications during childbirth (UNFPA, 2021). In rural areas, displacement caused by climate shocks often leads to a breakdown in maternal health services, limiting access to skilled birth attendants and emergency obstetric care (UNDRR, 2019). Additionally, the health impacts of climate change are not uniformly distributed. Poor women, particularly in rural and peri-urban African communities, face a disproportionate burden due to structural inequalities, inadequate access to healthcare, and higher exposure to environmental hazards. These intersecting risks underscore the role of climate

change as a threat multiplier for maternal health outcomes in emerging African economies (WHO, 2021).

Empirical studies have begun to quantify these effects. For instance, in a multi-country analysis, Grace et al. (2015) found a strong association between regional climate anomalies and increased maternal mortality in East Africa. Similarly, Chersich et al. (2020) demonstrated that heat exposure in pregnancy is linked with a 16% increase in the odds of maternal death. These findings support the growing consensus that climate action is integral not only to environmental protection but also to achieving Sustainable Development Goal 3 on maternal health.

2.1 Public Health Expenditure and Maternal Mortality

Public health expenditure has long been considered a critical determinant of health outcomes in low- and middle-income countries, including maternal and child health. The World Health Organization (2017) highlights that insufficient government health financing remains a major challenge in sub-Saharan Africa, where maternal mortality rates remain among the highest globally. While some African nations have improved their health budget allocations, the overall investment still falls short of the 15% benchmark set by the Abuja Declaration (WHO, 2016).

Empirical evidence supports the view that increased public health spending reduces mortality outcomes. For instance, Arthur and Oaikhenan (2017) find that public health expenditure significantly lowers child mortality in sub-Saharan Africa. Similarly, Novignon and Lawanson (2017) report a negative and statistically significant relationship between government health investment and under-five mortality across SSA countries. Although these studies primarily focused on child health, the implications extend to maternal mortality, given the shared reliance on healthcare access, infrastructure, and skilled birth attendance. In India, Barenberg, Basu, and Soylu (2017) provide direct evidence that public expenditure on healthcare leads to a reduction in infant and maternal mortality, suggesting that budgetary commitment plays a central role in improving reproductive health outcomes. The WHO (2018) further notes that countries with higher shares of prepaid public health spending (e.g., through taxes or social health insurance) tend to report better maternal health indicators. However, despite progress, many low-income African countries rely heavily on external health financing. For example, in 2015, external funding

accounted for 30% of health spending in low-income countries compared to less than 1% in high-income countries (WHO, 2017).

The mixed findings in some studies (e.g., Filmer, 1999; Rahman, Khanam, & Rahman, 2018) caution against oversimplification, suggesting that the effectiveness of public health spending also depends on governance quality, allocation efficiency, and absorptive capacity. Thus, while increasing public expenditure is necessary, it must be matched with efforts to ensure equitable distribution, minimize out-of-pocket payments, and improve health system performance to significantly lower maternal deaths in emerging African economies.

2.3 Public Health Expenditure and Climate Change

The intersection of climate change and public health financing is increasingly recognized as a critical area for both research and policy. Climate-induced health risks, ranging from heat-related illnesses and vector-borne diseases to water contamination and undernutrition, pose growing challenges for already resource-constrained health systems in low- and middle-income countries (Watts et al., 2021). In this context, the role of public health expenditure becomes particularly significant, not only as a means of responding to climate-related health shocks but also as a preventative investment in system-wide resilience.

There is growing empirical evidence suggesting that increased public spending on health can mitigate the adverse health outcomes of climate variability. For instance, studies have shown that well-financed healthcare systems are better equipped to respond to climate-driven disease outbreaks, provide heat-health early warning systems, and improve access to basic services during climate emergencies (Ebi et al., 2021; Dasgupta et al., 2023). A recent study by Patz et al. (2022) underscores that proactive public investment in climate-sensitive health programs (e.g., vaccination, sanitation, air quality monitoring) significantly reduces morbidity and mortality, especially among vulnerable populations such as children, the elderly, and pregnant women.

Moreover, climate change is expected to exacerbate existing inequalities in health financing. In sub-Saharan Africa and many parts of Asia, where public health systems are already underfunded, climate change increases the fiscal burden on governments, thereby complicating budgetary

allocations to health (OECD, 2021). According to the WHO (2023), countries with higher government health expenditure per capita tend to have more robust emergency preparedness and climate-health surveillance systems. In contrast, underfunded systems often resort to reactive and fragmented interventions, which increase long-term costs and reduce health outcomes. Emerging evidence also suggests that integrating climate adaptation into national health budgeting frameworks improves cost-efficiency. For example, resilience-focused spending, such as strengthening primary health care and deploying community health workers, can yield high returns by reducing climate-sensitive disease burdens (Watts et al., 2021; Singh et al., 2023). Nevertheless, there are significant data gaps and inconsistencies in how countries report climate-sensitive health spending, which limits comparability and effectiveness assessment. In sum, public health expenditure serves as both a buffer and a bridge in the face of climate change. Its strategic deployment is vital for reducing health vulnerabilities, especially maternal and child mortality, in climate-affected regions. As such, the literature increasingly advocates for integrated approaches that link climate policy with national health financing strategies.

3. Methodology and Data

This study employs a panel data econometric approach to examine the relationship between climate change (proxied by temperature), public health spending, and maternal mortality in selected emerging African economies. Specifically, the analysis assesses the short- and long-term impacts of rising temperatures and variations in government health expenditure on maternal mortality rates, thereby contributing to the discourse on the Sustainable Development Goals (SDGs), particularly SDG 3 (Good Health and Well-being) and SDG 13 (Climate Action).

Empirical Strategy

A three-stage estimation strategy was adopted. First, a Pooled Ordinary Least Squares (POLS) regression was estimated to establish the unconditional association between temperature and maternal mortality. This baseline model serves as a diagnostic to understand whether climate change has any statistically significant effect on maternal health outcomes without controlling for country-level heterogeneity. Second, the study estimated Fixed Effects (FE) and Random Effects (RE) panel models to control for unobservable, time-invariant country-specific characteristics that may influence maternal mortality, such as institutional quality, cultural practices, or historical healthcare infrastructure. Third, the model was augmented to include government health

expenditure as a share of GDP, to test whether domestic public health investment cofounded the effect of temperature on maternal mortality. Hausman specification tests were conducted to determine the appropriate model between fixed and random effects.

Model Specification

The general econometric model is specified as:

$$MMR_{it} = \alpha_0 + \beta_1 CC_{it} + \beta_2 GHE_{it} + \beta_3 (CC_{it} * GHE_{it}) + \mu_i + \lambda_t + \varepsilon_{it}$$

Where: MMRit is the maternal mortality rate per 100,000 live births in country i at time t; CCit denotes changes in average annual temperature (°C); GHEit represents government health expenditure as a percentage of GDP; CCit*GHEit is the interaction term used to test whether government health expenditure mitigates the impact of climate change on maternal mortality rate; μi captures country fixed effects; λt captures time effects (though not explicitly included in the main models, robustness checks consider their role); and ϵi is the idiosyncratic error term.

All models are estimated using robust standard errors to account for heteroscedasticity, and model fit is evaluated through R-squared, root mean square error (RMSE), and F-tests.

Data

This study draws on a panel dataset comprising annual observations for seven emerging African economies, Egypt, Ethiopia, Ghana, Kenya, Nigeria, Senegal, and South Africa, covering the period from 2000 to 2021. These countries were selected based on their regional diversity, classification as emerging economies, and the availability of consistent time series data. They also represent varying levels of vulnerability to climate change and public health investment, making them ideal case studies for examining the interplay between climate conditions, health expenditure, and maternal health outcomes.

The primary dependent variable is the Maternal Mortality Rate (MMR), defined as the number of maternal deaths per 100,000 live births. This indicator was obtained from the World Bank's World Development Indicators (WDI) and serves as a robust proxy for maternal health outcomes. Two key independent variables are employed. First, Temperature, measured as changes in average annual temperature in degrees Celsius (°C), captures the climate-related stress likely to affect maternal health directly or indirectly. This variable is sourced from reliable climate databases such

as the Climatic Research Unit (CRU) or Berkeley Earth. Second, Government Health Expenditure (GHE), expressed as a percentage of GDP, represents the extent of public investment in the health sector. This data is drawn from the WHO Global Health Expenditure Database and cross-verified with the World Bank to ensure accuracy and consistency.

The dataset provides a balanced panel structure over 22 years for each country, enabling robust estimation of both temporal and cross-sectional dynamics. The empirical strategy is designed to identify both the independent effects of temperature and public health spending on maternal mortality and their joint implications. In doing so, the analysis contributes timely and policy-relevant insights into the intersection of environmental change, fiscal health priorities, and maternal well-being, especially within the broader context of achieving the Sustainable Development Goals (SDGs).

Result

Empirical Strategy and Interpretation of Results

To investigate the relationship between climate change (proxied by temperature), public health spending, and maternal mortality in emerging African economies, a three-stage empirical strategy was adopted. This approach provides a logical and robust progression from a basic assessment of the temperature-mortality link, through model specification tests, to the inclusion of a key policy variable (government health expenditure), ultimately enabling a clearer understanding of potential policy levers for achieving Sustainable Development Goal 3 (Good Health and Well-being).

1. Baseline Estimation: Pooled OLS Model

The first model reported in Table I, establishes the unconditional association between average annual temperature and maternal mortality rate (MMR) using a pooled OLS framework. The results show a statistically significant and positive relationship between temperature and maternal mortality: a 1°C increase in average temperature is associated with a 2.78-unit rise in maternal deaths per 100,000 live births ($p < 0.01$). The model explains approximately 6.1% of the variation in maternal mortality ($R^2 = 0.061$). The F-statistic of 9.93 with $p = 0.00196$ indicates that the model is statistically significant overall.

Table I: Baseline Pooled OLS Regression

	(1)

VARIABLES	POLS
Temp	2.782***
	(0.883)
Constant	3.303
	(22.29)
Observations	154
R-squared	0.061
country effect	NO
year effect	NO
Rmse	36.85
F-test	9.928
Prob > F	0.00196

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

While useful as a starting point, this model does not account for unobserved heterogeneity across countries or over time. This limitation motivates the estimation of panel models with fixed and random effects.

2. Country Fixed Effects and Model Selection

The second stage introduces country fixed effects (FE) to control for time-invariant heterogeneity (e.g., institutional quality, geography) across countries. The temperature coefficient increases to 4.42, but loses statistical significance (p > 0.1) due to increased standard errors, suggesting that the relationship may be confounded by omitted variables or varying baseline country characteristics (Table 2).

Table 2: Fixed Effects Estimation of the Impact of Climate Change on Maternal Mortality

	(1)	(2)	(3)	(4)
VARIABLES	POLS	FE	FE	FE
Temp	2.782***	4.421	4.421	4.421
	(0.883)	(2.926)	(2.926)	(2.926)
Constant	3.303	-37.71	-37.71	-37.71
	(22.29)	(73.25)	(73.25)	(73.25)
Observations	154	154	154	154
R-squared	0.061	0.015	0.015	0.015
country effect	NO	YES	YES	YES
year effect	NO	NO	NO	NO
rmse	36.85	20.95	20.95	20.95
F-test	9.928	2.282	2.282	2.282

Prob > F	0.00196	0.133	0.133	0.133
Number of countryid		7	7	7
F-test(u_i=0)		54.06	54.06	54.06
Prob > F(u_i=0)		0	0	0

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Despite the insignificant result, the F-test of the fixed effects model (Prob > F = 0.133) and the Hausman test support the use of fixed over random effects, as indicated by the significant F-test of country effects (F = 54.06, p = 0.000). This suggests substantial heterogeneity across countries, justifying fixed effects specification. However, random effects (RE) results are also presented for comparison, showing a positive but moderately smaller coefficient (3.85) than the fixed effects estimate.

Table 2: Random Effects Estimation of the Impact of Climate Change on Maternal Mortality

VARIABLES	(1) POLS	(2) FE	(3) FE	(4) FE	(5) RE
Temp	2.782***	4.421	4.421	4.421	3.851
	(0.883)	(2.926)	(2.926)	(2.926)	(2.375)
Constant	3.303	-37.71	-37.71	-37.71	-23.46
	(22.29)	(73.25)	(73.25)	(73.25)	(60.96)
Observations	154	154	154	154	154
R-squared	0.061	0.015	0.015	0.015	
country effect	NO	YES	YES	YES	YES
year effect	NO	NO	NO	NO	NO
Rmse	36.85	20.95	20.95	20.95	20.89
F-test	9.928	2.282	2.282	2.282	
Prob > F	0.00196	0.133	0.133	0.133	
Number of countryid		7	7	7	7
F-test(u_i=0)		54.06	54.06	54.06	
Prob > F(u_i=0)		0	0	0	
chi-squared					2.629
Prob > chi2					0.105

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

3. Augmented Model with Government Health Expenditure

Recognizing that public health investment is an important determinant of maternal health outcomes, the third model introduces government health expenditure (GHE) into the regression.

The results indicate that GHE has a strong and statistically significant independent effect on maternal mortality. Specifically, the GHE coefficient is negative and significant (–14.33, $p < 0.01$) in the fixed effects model, implying that a 1 percent increase in government health expenditure as a share of GDP is associated with a reduction of approximately 14 maternal deaths per 100,000 live births (Table 3).

Notably, the inclusion of GHE substantially alters the estimated effect of temperature. While temperature was positive and statistically significant in earlier specifications, its coefficient declines to 0.48 and becomes statistically insignificant once GHE is introduced. This pattern suggests that government health expenditure explains a significant portion of the variation in maternal mortality that was previously attributed to temperature changes. Rather than providing direct evidence of a mitigation or buffering effect, this result indicates that GHE may act as an important confounding or conditioning factor in the climate–maternal mortality relationship. Consequently, the findings highlight the dominant role of public health investment in shaping maternal health outcomes, while suggesting that the direct effect of temperature becomes less pronounced once health system capacity is accounted for.

Table 3: Climate Change and Government Health Expenditure as Determinants of Maternal Mortality (FE and RE Models)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	POLS	FE	FE	FE	RE	FE
Temp	2.782***	4.421	4.421	4.421	3.851	0.482
	(0.883)	(2.926)	(2.926)	(2.926)	(2.375)	(0.970)
GHE						-14.33***
						(3.128)
Constant	3.303	-37.71	-37.71	-37.71	-23.46	84.64***
	(22.29)	(73.25)	(73.25)	(73.25)	(60.96)	(27.47)
Observations	154	154	154	154	154	154
R-squared	0.061	0.015	0.015	0.015		0.176
country effect	NO	YES	YES	YES	YES	YES
year effect	NO	NO	NO	NO	NO	NO
Rmse	36.85	20.95	20.95	20.95	20.89	34.65
F-test	9.928	2.282	2.282	2.282		16.11
Prob > F	0.00196	0.133	0.133	0.133		4.54e-07
Number of countryid		7	7	7	7	
F-test(u_i=0)		54.06	54.06	54.06		
Prob > F(u_i=0)		0	0	0		

chi-squared					2.629		
Prob > chi2					0.105		

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Random effects estimation also supports this finding, yielding a similar GHE coefficient of -6.87 ($p < 0.05$) and a slightly higher temperature coefficient (4.39, $p < 0.1$), as shown in Table 3 (Column 7). The model fit improves markedly (R^2 rises to 0.176), and the Hausman test ($p = 0.0347$) confirms the preference for fixed effects.

Table 4: Robustness Checks with Government Health Expenditure and Random Effects Consideration

VARIABLES	(1) POLS	(2) FE	(3) FE	(4) FE	(5) RE	(6) FE	(7) RE
Temp	2.782***	4.421	4.421	4.421	3.851	0.482	4.386*
	(0.883)	(2.926)	(2.926)	(2.926)	(2.375)	(0.970)	(2.372)
GHE						-14.33***	-6.866**
						(3.128)	(3.413)
Constant	3.303	-37.71	-37.71	-37.71	-23.46	84.64***	-25.47
	(22.29)	(73.25)	(73.25)	(73.25)	(60.96)	(27.47)	(60.52)
Observations	154	154	154	154	154	154	154
R-squared	0.061	0.015	0.015	0.015		0.176	
country effect	NO	YES	YES	YES	YES	YES	YES
year effect	NO	NO	NO	NO	NO	NO	NO
Rmse	36.85	20.95	20.95	20.95	20.89	34.65	20.68
F-test	9.928	2.282	2.282	2.282		16.11	
Prob > F	0.00196	0.133	0.133	0.133		4.54e-07	
Number of countryid		7	7	7	7		7
F-test(u_i=0)		54.06	54.06	54.06			
Prob > F(u_i=0)		0	0	0			
chi-squared					2.629		6.724
Prob > chi2					0.105		0.0347

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The set **of results in Table 4 that serve as robustness checks with government health expenditure and random effects consideration** builds upon this finding. Model 7 includes both temperature and GHE using a **random effects specification**, and both variables are now statistically significant: temperature (coefficient = 4.386, $p < 0.1$) and GHE (coefficient = –6.866, $p < 0.05$). This suggests that even when controlling for unobserved heterogeneity, both rising

temperatures and low government health spending independently contribute to maternal mortality. Notably, the inclusion of GHE increases the explanatory power of the model substantially (as evidenced by the improved RMSE and chi-squared statistics), highlighting its policy relevance.

Taken together, these results follow a logical estimation sequence. The baseline model (Table 1, Model 1) establishes a significant relationship between climate change and maternal mortality. Fixed and random effects models test the robustness of this relationship by accounting for country-specific unobserved effects. Then, in the final stage, the inclusion of government health expenditure helps isolate its role in mitigating the harmful impact of climate change on maternal health. These results indicate that while climate change poses a threat to maternal health outcomes, **targeted public health investment can serve as a powerful countervailing force.**

From a **policy perspective**, these findings have critical implications for Sustainable Development Goals (SDGs), particularly SDG 3 (Good Health and Well-being) and SDG 13 (Climate Action). Strengthening public health systems, particularly in response to rising climate threats, should be a top priority for African governments. Moreover, the significant variation across model specifications emphasizes the need for country-specific strategies that consider both environmental vulnerability and institutional health financing capacity.

5. Discussion of Results

The baseline pooled OLS results indicate a positive and statistically significant association between rising temperatures and maternal mortality. This finding is consistent with the growing empirical literature that identifies climate change as an indirect but powerful determinant of maternal health outcomes in low- and middle-income countries (Grace et al., 2015; Chersich et al., 2020). From a theoretical perspective, this aligns with the Vulnerability and Adaptation Framework (IPCC, 2014), which emphasizes that increased exposure to climatic stressors—such as heat waves and extreme weather events-can exacerbate health risks, particularly for pregnant women. The positive temperature effect likely reflects multiple transmission channels documented in the literature, including heat stress during pregnancy, increased prevalence of climate-sensitive diseases, food insecurity, and disruptions to healthcare access caused by extreme weather events (Kuruppu & Willie, 2015; UNFPA, 2021). In African contexts, where health systems are often

fragile and geographic exposure to climate risks is high, these channels can interact to elevate maternal mortality risks. Thus, the baseline findings reinforce the view of climate change as a "threat multiplier" for maternal health in vulnerable economies.

Once country fixed effects are introduced, the temperature coefficient becomes statistically insignificant, although it remains positive. This result highlights the importance of accounting for unobserved, time-invariant country characteristics such as institutional quality, baseline health infrastructure, geography, and socio-cultural factors. The Hausman and F-tests strongly support the fixed effects specification, indicating that cross-country heterogeneity plays a substantial role in shaping maternal mortality outcomes. This finding is consistent with prior studies suggesting that the climate–health relationship is highly context-dependent (Ebi & Semenza, 2008; WHO, 2021). Countries differ significantly in their adaptive capacity, public health preparedness, and exposure levels, which can dampen or amplify the observable impact of temperature changes. Consequently, failure to control for such heterogeneity may overstate the direct role of climate variables in explaining maternal mortality.

The inclusion of government health expenditure (GHE) in the augmented model yields one of the most robust findings of the study. Across both fixed and random effects specifications, GHE exhibits a strong, negative, and statistically significant association with maternal mortality. This result is firmly grounded in Grossman's Human Capital Model (Grossman, 1972) and the Health Production Function framework, which emphasizes health spending as a critical input into improved health outcomes. Empirically, this finding is consistent with previous evidence from Africa and other developing regions showing that increased public health spending reduces mortality by improving access to skilled birth attendance, emergency obstetric care, and maternal health infrastructure (Arthur & Oaikhenan, 2017; Barenberg et al., 2017). The magnitude of the estimated effect underscores the central role of fiscal commitment to health in addressing preventable maternal deaths.

The robustness checks using random effects estimation further reinforce the importance of jointly considering climate variables and public health expenditure. In these models, both temperature and GHE remain statistically significant, indicating that rising temperatures and inadequate health

financing independently contribute to maternal mortality. This finding is consistent with the Sustainable Livelihoods Framework (Chambers & Conway, 1992), which emphasizes that environmental shocks and institutional capacity interact to shape welfare outcomes.

The results therefore suggest that while climate change poses an underlying risk to maternal health, the severity of its impact is closely linked to the strength of health systems. Countries with higher public health spending are better positioned to maintain service delivery during climate shocks, invest in preventive care, and support vulnerable populations. This interpretation aligns with recent evidence highlighting the role of public investment in enhancing health system resilience to climate-related risks (Watts et al., 2021; Ebi et al., 2021).

Policy Implications and SDG Linkages

Taken together, the findings underscore the importance of integrating climate considerations into health financing strategies. While climate change remains an important determinant of maternal mortality, the results emphasize that public health expenditure plays a dominant and policy-relevant role in shaping outcomes. This has direct implications for SDG 3 (Good Health and Well-being), particularly the target of reducing global maternal mortality, as well as SDG 13 (Climate Action), which calls for strengthening adaptive capacity to climate-related risks.

Rather than viewing climate and health policies in isolation, the evidence supports a more coordinated approach in which investments in public health systems are recognized as essential complements to climate adaptation strategies. For emerging African economies facing increasing climate stress and fiscal constraints, prioritizing efficient and equitable health spending may offer one of the most effective pathways for safeguarding maternal health in the face of environmental change

6. Conclusion

This study examined the relationship between climate change, public health expenditure, and maternal mortality in emerging African economies using panel data methods. The analysis provides new empirical evidence on how environmental stressors and institutional capacity jointly shape maternal health outcomes in a region that remains highly vulnerable to both climate shocks and health system constraints.

The findings indicate that rising temperatures are positively associated with maternal mortality in baseline estimations, supporting the growing body of literature that identifies climate change as a significant indirect determinant of maternal health. However, once country-specific heterogeneity is accounted for through fixed effects, the direct effect of temperature becomes statistically weaker, suggesting that structural and institutional differences across countries play an important role in mediating climate-related health risks. A key result of the study is the consistently strong and negative association between government health expenditure and maternal mortality. Higher public health spending is shown to significantly reduce maternal deaths across model specifications, highlighting the central role of health system investment in improving maternal outcomes. Importantly, the inclusion of government health expenditure substantially alters the estimated relationship between temperature and maternal mortality, indicating that health spending explains a meaningful share of the variation previously attributed to climate factors. While this does not provide direct evidence of a buffering or mitigation effect, it underscores the importance of public health financing as a critical conditioning factor in climate-health dynamics.

Taken together, the results suggest that climate change and public health expenditure independently influence maternal mortality outcomes in Africa. This implies that policies aimed at reducing maternal mortality must address both environmental vulnerability and health system capacity. Climate adaptation strategies that are not accompanied by sustained investments in public health infrastructure, skilled personnel, and service delivery are unlikely to achieve meaningful reductions in maternal mortality. From a policy standpoint, the study reinforces the need for African governments to prioritize health financing as part of broader climate resilience strategies. Strengthening public health systems can reduce baseline vulnerability and enhance the capacity to cope with climate-related health shocks, thereby contributing to progress toward Sustainable

Development Goal 3 (Good Health and Well-being) and Sustainable Development Goal 13 (Climate Action).

Finally, the study acknowledges certain limitations. The absence of an interaction term between climate variables and health expenditure constrains causal interpretation regarding mitigation effects. Future research could extend this analysis by explicitly modeling interaction effects, exploring nonlinear climate impacts, and incorporating additional climate indicators such as extreme weather events. Despite these limitations, the study provides robust evidence that public health expenditure remains a pivotal policy instrument for improving maternal health outcomes in the context of climate change in emerging African economies.

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