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Article in *Journal of Social and Economic Development* · March 2022

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The implications of climate change and extreme weather events for fiscal balance and fiscal policy in Africa

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Published online: 4 March 2022

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Abstract

African countries quite often experience weather-related events as a result of climate variabilities. In this study, we investigate the effects of climate change and the incidence of extreme weather events on fiscal balance and the broad implications for fiscal policy formulation in Africa. We employ the system GMM, fixed-effects and random-effects estimation strategies over the period 1990–2017. We find that increases in temperature change anomaly which implies a warmer climate in a meteorological year worsens fiscal balance in Africa. Our findings also reveal that weather-related events may have a significant impact on fiscal balance, if the damage caused is large and consequential. Furthermore, African countries with relatively strong institutions and adaptive capacities tend to modulate the impact of temperature change anomaly and extreme weather events on fiscal balance. We forecast that the frequent incidence of climatic disruptions and extreme weather events which are considered as external shocks may toughen the fiscal consolidation efforts and debt sustainability measures of some African governments.

Keywords Climate change · Extreme weather events · Fiscal balance · Institutions · Africa

JEL Classification H61 · H68 · Q51 · Q54 · Q58

Introduction and motivation

Climate change according to the World Meteorological Organisation (WMO) encompasses all forms of climatic variability on time scale that spans over a decade and can be observed through changes in the average weather patterns all over the world. Climate change poses a threat to global prosperity, survival of future generations and it is currently ranked by the World Economic Forum (2019) as the greatest threat to the planet. The Intergovernmental

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Panel on Climate Change (IPCC) estimates that global temperature will increase by about 2.8 °C over the next century if the necessary emission control and remedial measures are not taken seriously (IPCC 2007). This is projected to increase not just the severity but also the frequency of extreme weather events in the twenty-first century (IPCC 2012, 2007). This is particularly true because the records of the WMO indicates that 14 of the 15 warmest years have all taken place in the twenty-first century. There is enough available scientific support (see Kireyev 2018; Lis and Nickel 2010; IPCC 2007) to back the assertion that the rise in the severity and frequency of extreme weather events are due to climate change disruptions. Also, the Center for Research on the Epidemiology of Disasters (2017) asserts that more than 90 percent of disasters that have occurred globally in the last two decades emanates from climate-related causes. Extreme weather events are a special type of natural disasters, particularly meteorological, hydrological and climatological that may require a declaration of a state of emergency or a call for international assistance. In Africa, extreme weather events are mainly caused by storms, extreme temperatures (heat wave or cold wave), floods, wildfires landslide and droughts. According to the Global Climate Risk Index report (2017), more than half a million people died due to 11 thousand extreme weather events between 1996 and 2015. This resulted to a damage cost of three trillion dollars due to floods, storms, heatwaves and other climate-related disasters. In Africa, about 51,569 people have been killed and 412 million people adversely affected due to 1,381 different forms of weather events over the period 1990 to December 2019 as recorded in the emergency events database maintained by Center for Research on the Epidemiology of Disasters (CRED). This has led to a total damage cost of over US\$ 19.78 billion to property, crops and livestock. Climate change and extreme weather events have led to loss of human life, destructions to property, human capital and may have stalled productivity. Available evidence (IMF 2017) indicates that an increase in average temperature by 1 °C can reduce GDP per capita by about 1.5 percent in sub-Saharan Africa. Other studies (see Cashin et al. 2017; Hallegatte et al. 2016) indicate that extreme weather events have detrimental effects on economic activity in Africa. Few others such as Bachner et al. (2019); Melecky and Raddatz (2015); Noy and Nualsri (2011); Lis and Nickel (2010) claim that natural disasters and extreme weather events can have serious issues for public finances and budget balances. This presupposes that climate change and extreme weather events have dire consequences for fiscal policy all over the world. This is very evident in the billions of dollars committed by developed and developing nations alike to adapt to climate change impacts and also to mitigate future climatic disruptions. An important illustration is the pledge made by developed countries as enshrined in the United Nations' Framework Convention on Climate Change (UNFCCC) since 2009 to support developing countries mitigate and adapt to climate change with about 100 billion USD per annum until 2020.

The fiscal implications of climate change and extreme weather events cannot be denied and a cause for major concern. This concern is very real in most African countries because they already have limited fiscal space and run on high fiscal deficits (see Fig. 1).

Moreover, there are urgent and burgeoning issues with poverty and inequality that require critical attention within the limited fiscal space. It is even more threatening for Africa because the continent is considered to be the most vulnerable to climate change impacts (Farid et al. 2016; World Bank 2014) and further inactions will have severe repercussions. That notwithstanding, most African governments prioritize job creation and poverty alleviation at the expense of environmental concerns as alluded to by Mburia (2015). Available evidence can be found in the 2017 ranking of countries with strong adaptive capacity to climate change by Notre Dame Global Adaptation Index (ND-GAIN). Countries such as Norway, New Zealand, Finland, Sweden and Australia

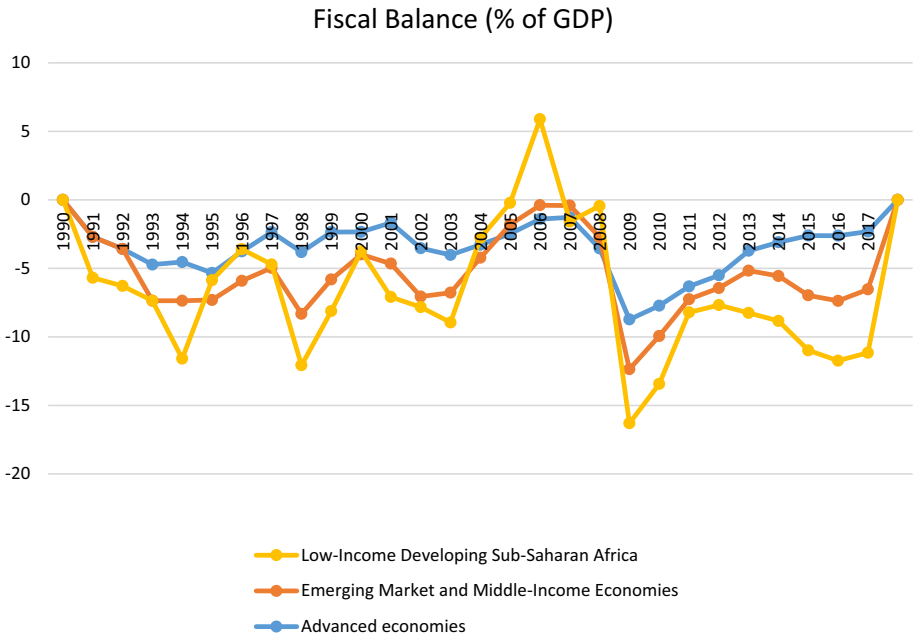


Fig. 1 Regional distribution of fiscal balance for the period 1990–2017. *Source:* Authors construct from IMF data (2019)

ranked highest in that order, while African countries such as Niger, Sudan, Democratic Republic of Congo, Central African Republic, Eritrea, Chad and Somalia completed the list in a descending order. When it comes to country's preparedness and resilience to climate change impacts, only Mauritius, Morocco and South Africa garnered an average score in the rankings by Notre Dame. This makes most African countries very vulnerable to climatic disruptions. It is necessary to consider the fiscal aspect of climate change because it may have serious implications for debt sustainability and the economic survival of future generations. More so, when the United Nations Climate Change (UNCC 2018) says that, climate change is gradually increasing the cost of capital and recent projections indicate there will be an additional USD 168 billion in debt payments over the next decade especially among countries that are very vulnerable to climate change. Consequently, our study investigates the effects of climate change and extreme weather events on fiscal balance in Africa and the implications for fiscal policy formulation. Our study departs from the general trend of finding the impact of climate change and extreme weather events on growth (see Mendelsohn 2013; Dell et al. 2012; Cavallo and Noy 2010), estimating the economic cost of climate change (see Mekonnen 2014; Stern 2006) and the fiscal implications of natural disasters (see Bachner et al. 2019; Ouattara and Strobl 2013; Noy and Nualsri 2011).

Furthermore, we investigate the extent to which institutions and adaptive capacity modulate the impacts of extreme weather events and climate change on fiscal balance. Our study is the first attempt to study these phenomena in a more comprehensive manner in the context of Africa. The subsequent sections discuss the literature, methods, results, conclusion and policy recommendations.

Literature review

The budget deficits and debt of most developing nations appear very high and in some cases are being overstretched partly due to economic mismanagement and misplaced priority spending. To say the least, the burgeoning threat of climate change impact appears scary considering the fact that most African countries have fiscal challenges. It becomes very blurred to picture how current climate change and more daring future climatic variabilities will dictate government fiscal stance; this is the main focus of this present study. This present study focuses on Africa because there is a general consensus that low-income countries (particularly those in Africa) are more vulnerable to both current and future climate variabilities than high income ones (Farid et al. 2016; World Bank 2014) because they are dependent on climate sensitive sectors such as agriculture, fisheries and forestry. The main reason for Africa's vulnerability to climate change impacts according to Barr et al. (2010) is because of high adaptation deficit in low-income countries where there is mostly lack of financial, economic and institutional capacity to adapt more effectively. Stromberg (2007) and Dayton-Johnson (2006) argue that the main reasons for high vulnerabilities in developing countries are because of warmer climate, high income inequality gap, poor macro-economic conditions and ineffective governments. The ensuing literature review is divided into four sections including a discussion on the relationship between climate change, natural disasters and economic growth; determinants of fiscal balance; extreme weather events and fiscal balance; and climate change and fiscal policy.

Climate change and natural disaster on economic growth

Literature is generally dense on the macroeconomic implications of climate change and extreme weather events and the economic cost of these occurrences. The main macro-response variable usually considered in the literature is economic growth. For example, Mekonnen (2014) investigates the economic cost of climate change and climate finance for Africa and found Africa to be the region of the world that is mostly vulnerable to climate change. The paper mentioned that the adaptation cost for Africa over the next fifteen years is in the range of 20–30 billion dollars per annum and the funding that comes for adaptation purposes is far less than the required amount. Relatedly, Dell et al. (2012) study the aggregate economic effects of historical fluctuations in temperature within countries and found higher temperatures to substantially reduce economic growth among poor countries but has less effect in rich countries and the effect of the temperature rise is more pronounced in sub-Saharan Africa than the rest of the world. Specifically, a temperature rise of one degree Celsius in a given year was found to reduce economic growth by 1.1 percentage points. Also, Alagidede et al. (2014) and Odusola and Abidoye (2012) established in their studies that, increases in temperature reduces economic performance in Sub-Saharan Africa and Africa, respectively.

Determinants of fiscal balance

Tujula and Wolswijk (2007) studied on OECD countries and found changes in budget balances to be affected by debt growth, macroeconomic developments and political factors. The variables introduced into the model include; changes in previous year's debt ratio, interest rate, election year, asset market price, inflation, real GDP growth rate, unemployment and type of government. Similarly, but centered on European countries, Bayar and

Smeets (2009) modeled the determinants of fiscal deficit with unemployment, GDP growth rate, long-term interest, lagged debt-to GDP ratio, elections and the ideological complexities of government as explanatory variables. Lis and Nickel (2010) identify extreme weather event, lagged change in debt, lagged change in real interest rate, GDP growth, inflation and election as influencers of budget balances in 138 countries. More recently, Barisik and Baris (2017) find inflation, GDP growth, and indicators of institutions including voice and accountability, political stability and regulatory quality to significantly influence budget deficits for 123 countries for the period 2002–2014.

Extreme weather events and fiscal balance

Studies that have undertaken an econometric analysis of the fiscal implications of extreme weather events or catastrophes include Lis and Nickel (2010); Ouattara and Strobl (2013) and Melecky and Raddatz (2015). Others such as Bräuer et al. (2009); Margulis and Narain (2010); Osberghaus and Reif (2010); Jones et al. (2013) and Gilmore and St. Clair (2018) provide a complementary qualitative analysis. While Ouattara and Strobl (2013) found a detrimental short run effects on government spending of hurricane strikes in the Caribbean, Melecky and Raddatz (2015) found countries with sophisticated and developed debt and insurance market to suffer less real consequences from a disaster. Their study focused mainly on high and middle income countries.

Climate change, extreme weather events and fiscal policy

There is scant extant literature on the fiscal dimension of climate change. This was alluded to by Bachner et al. (2019); Lis and Nickel (2010) and CEPS and ZEW (2010). CEPS and ZEW (2010) identify the following as the six main drivers behind the fiscal impact caused by climate change in the European Union (EU); the degree of exposure to gradual and extreme weather events; the preparedness level put in place by areas already prone to risk; the state's liabilities for damages; the potential and impacts of autonomous adaptation and remedial actions; the cross border effects of climate change; the fiscal capacity of member states; and the role of the EU. They also found the following fiscal implications of climate change in their exploratory study; compensation for the loss of agricultural lands through desertification, relocation of infrastructure and building protective infrastructure, compensation for real estate taken over by floods, cost of monitoring and cost of providing early warning information and health expenditure among a host of others.

The study by Leppänen et al. (2017) for 78 regions in Russia revealed an inverse relationship between temperature and expenditure per capita. Thus, increases in temperature reduces expenditure in cold regions and this effect attenuates non-linearly in warmer regions. Bachner et al. (2019) developed an assessment framework in their study of how climate change adaptation affect public budget in Austria. They found that public adaptation can lead to positive macroeconomic effects on GDP, employment and welfare and that government expenses on adaptation can generate far greater revenue which can lead to a surplus in the budget balance. Kireyev (2018) reviewed the macro-fiscal challenge posed by climate change in Djibouti and conclude that the country is very susceptible to climate change and the related cost are enormous. The paper called for immediate investment in adaptation and mitigation which should have future benefits in terms of reducing related cost and these investments should be built into long-term future projections. Bachner et al. (2019) identify the following as climate change impacts on public

budgets; temperature or precipitation may affect agriculture productivity, system reliability of hydropower, wind and PV electricity generation. It can also cause a change in tourism demand and can lead to an increase in cooling energy demand or heating energy demand. Also, it may lead to worker productivity losses due to humidity and heat.

Study by Bird et al. (2016) focuses on how public funds have been allocated to finance climate change actions through the national budgets of selected African countries. Most of these public spending are assumed to be in alignment with the national agenda of these countries. These include, the cost of building institutional capacity to plan and manage climate change, including early warning and monitoring, cost of raising awareness about climate change, expenditure on hydropower alternatives due to fall in water levels in dams, higher demand for water due to changes in water quantity and quality. Also extra cost of irrigation due to dryness of water bodies, expenses on a shift from rain-fed agriculture to irrigation agriculture, physical damage to existing infrastructure and hence increased maintenance cost, increased health expenses due to climate sensitive diseases, cost of acquiring and installing energy efficient systems, extra cost of climate proofing infrastructure and cost of tree planting exercises and forest conservation. According to the study, the agricultural ministry and water and energy ministries account for a chunk of the budgetary spending on climate change. Most of these activities are directed more toward adaptation than mitigation.

The closest to our study however, is the paper by Lis and Nickel (2010) on the impact of extreme weather events on budget balances and implications for fiscal policy. They consider only large-scale extreme weather event in a large panel data set up of 138 countries over the period 1985–2007. Lis and Nickel (2010) found extreme weather events to have detrimental effects on budget balances between the range of 0.23% and 1.1% depending on the region. They found the effect to be much higher for developing countries than others among a set of control variables that include inflation, lagged change in debt ratio, lagged change in interest rate, real GDP growth and elections. They also found insignificant results for OECD and EU countries. According to the paper, the transmission mechanism of extreme weather events to fiscal policy can either be direct or indirect. The direct effects are the immediate provision of relief support to surviving victims and the expenditure on public disaster response. Indirectly, it can lead to low productivity and reduced wealth, low tax revenues and a need for social support payments. Most of the studies identified above concentrated on natural disasters in general and not extreme weather events or climate change and most are based in the developed countries or developing countries as a whole. Our study differs from that of Lis and Nickel's in so many ways. We focus on the effects of climate change and extreme weather events on budget balance in Africa. We also concentrate on the roles institutions and adaptive capacity play in moderating the effects of extreme weather events and climate change on fiscal balance. We also include conflicts and unemployment as control variables. It is worth mentioning that how the fiscal issue of climate change is dealt with depends on the country and government policies in place. A large strand of literature (see Hascic et al. 2015; Kaminker and Stewart 2012; Buchner et al. 2011) argue for robust methods to be put in place in order to secure private funding. Others think that climate change spending should be part of the annual budget process. UNDP (2015), for example, asserts that governments would find it difficult to address the economic, social and environmental impacts of climate change unless it is integrated into national planning systems and budgetary processes due to its cross-cutting nature. This debate may be beyond the scope of this study and this may be a gap for future research.

Summary of literature and gaps

The extant-related literature has largely focused on the implications climate change and natural disasters have on economic growth and mostly conclude that climate change and natural disasters are detrimental to growth. Others have focused on how natural disasters such as hurricanes and earthquakes and extreme weather events affect public budget and budget balance and these studies are mainly centered in the advanced and middle income countries. Most of these studies ignored the effects of temperature change and weather-related events on fiscal balance in developing countries and Africa. This study departs from these studies by largely focusing on climate change and weather-related events and their apparent effects on fiscal deficit in Africa. In addition, this study addresses how adaptive capacities and institutions could influence fiscal deficit in an African setting.

Methods

Model specification, variable measurement and a priori expectations

Our model takes root from the model used by Lis and Nickel (2010) who study on the impact of large-scale extreme weather events on budget balances. They regress large-scale extreme weather events and a set of controls (lag change in debt ratio, real GDP growth, inflation, lag change in interest rate and elections) on change in budget balance. However, our specified models take a dynamic form as fiscal balance is predicted to depend on its lagged value and this is acknowledged and used by Lis and Nickel (2010) for robustness. Therefore, our models take these forms;

Model 1: The effects of climate change and weather events on fiscal balance

$$\text{Fisbal}_{it} = \alpha_1 \text{Fisbal}_{it-1} + \alpha_2 C \lim \Delta_{it} + \beta' X_{it} + \mu_i + \mu_t + \varepsilon_{it} \quad (1a)$$

$$\text{Fisbal}_{it} = \sigma_1 \text{Fisbal}_{it-1} + \sigma_2 \text{WeatherEvents}_{it} + \beta' X_{it} + \varphi_i + \varphi_t + \gamma_{it} \quad (1b)$$

Model 2: The moderating effects of institutions and adaptive capacity on Fiscal balance

$$\text{Fisbal}_{it} = \omega_1 \text{Fisbal}_{it-1} + \omega_2 (\text{WeatherEvents}_{it} * \text{Institutions}_{it}) + \beta' X_{it} + \eta_i + \eta_t + \tau_{it} \quad (2a)$$

$$\text{Fisbal}_{it} = \eta_1 \text{Fisbal}_{it-1} + \eta_2 (\text{WeatherEvents}_{it} * \text{Adaptivecap}_{it}) + \beta' X_{it} + \theta_i + \theta_t + \omega_{it} \quad (2b)$$

Model 3: The moderating effects of institutions on Fiscal balance—climate change

$$\text{Fisbal}_{it} = \pi_1 \text{Fisbal}_{it-1} + \pi_2 (C \lim \Delta_{it} * \text{Institutions}_{it}) + \beta' X_{it} + \psi_i + \psi_t + \lambda_{it} \quad (3)$$

The outcome variable in all the models is fiscal balance (Fisbal_{it}) measured as overall budget balance as a percentage of GDP in country i and time t . Overall balance is computed as the difference between government revenue and government expenditure. A positive balance means a surplus, while a negative balance means a deficit. The lag of fiscal balance (Fisbal_{it-1}) is introduced as past fiscal balances has significant roles to play in determining the current fiscal balance. It is expected that high fiscal deficit in the past

will send a signal to governments to put in measures in reducing the future deficits hence a positive nexus is expected.

Our main independent variables are climate change and weather events. Climate change ($\text{clim}\Delta_{it}$) is the main independent variable of interest in Model (1a) and it is measured by temperature change anomaly in a meteorological year. Temperature change anomaly indicates a departure from a 30-year long-term average (1951–1980) with positive values indicating a warmer climate while a negative value indicates a cooler value than the long-term reference value. Climate change is expected to have a negative effect on fiscal balance because of the required or related cost for adaptation and mitigation.

Weather event ($\text{WeatherEvents}_{it}$) is the main independent variable of interest in Model (1b) Weather event is measured as a count variable based on certain set criteria and decision rule. An event is counted if at least a weather event occurs within a year and 0 otherwise. Multiple counts are considered within a year depending on how many times weather events occur. Three alternative classifications of weather events are considered. For an event to be considered and entered in the Emergency Events database (EM-DAT), at least one of the following criteria need to be fulfilled; ten (10) or more people reported killed, hundred (100) or more people reported affected, a declaration of a state of emergency, a call for international assistance. Our first classification which we call “Weather Event 1” follows exactly this criterion which is used by EM-DAT under disaster sub-group climatological, hydrological or meteorological.

Secondly, we classify an occurrence as “Weather Event 2” (large-scale or extreme weather event) if a weather event caused at least one of the following; the number of people who died as a result are not less than one thousand (1000), the number of persons affected are more than one hundred thousand (100,000), the estimated damage caused by the weather event is at least one billion US dollars. This same classification (extreme weather event) has been used by Lis and Nickel (2010) and Gassebner et al. (2010). The reason they give is that, for a weather events to have substantial effect on budget balance, it needs to be large enough.

We created a third weather event category and named it “Weather Event 3” as a middle ground between large-scale extreme weather event and the basic requirement for an event to be considered weather event. Weather Event 3 requires the following criteria to be fulfilled to be classified as such; the number of people who died as a result are not less than one hundred (100), the number of persons affected are more than one thousand (1000), the estimated damage caused by the weather event is at least one million US dollars. The reason for creating “Weather Event 3” is that African countries already have limited fiscal space and any disturbance such as weather events may have grave implications for fiscal balance. This event need not be large as in Weather Event 2. We, however, expect all weather events variables to have negative effects on fiscal balance because of the large amounts of funds needed for the immediate provision of relief support to surviving victims and the expenditure on public disaster response.

In Model 2 and Model 3, Eqs. (2a, 2b and 3), we seek to find how institutions (Institutions_{it}) and adaptive capacity (Adaptivecap_{it}) modulate the relationship between weather events and temperature change anomaly on one hand and fiscal balance on the other hand. Institution is measured following the approach by Kaufmann et al. (2011), where institution is computed as an average of these six indicators; control of corruption, government effectiveness, political stability, regulatory quality, rule of law and voice and accountability. Institution ranges from -2.5 to 2.5 with higher values indicating stronger institution. We expect countries with relatively strong institutions to experience less impact of weather events and temperature change on fiscal balance while weak institutions should

depict a converse effect. Also, adaptive capacity measured by Notre Dame Global Adaptation Index (ND-GAIN) basically assesses a country's level of vulnerability to climate change impacts as well as readiness and preparedness to make use of adaptation investment. ND-GAIN ranges from 0 to 100 with higher values indicating strong adaptive capacity. It is expected that countries with strong adaptive capacities will absorb most of the effects of weather events on fiscal balance.

“X” is a vector of control variables that affect fiscal balance identified from literature. These variables are real GDP growth rate, inflation, unemployment, real interest rate, debt ratio, elections and conflicts.

Real GDP growth rate is measured by the annual growth rate of gross domestic product. We expect a positive relationship between growth rate and fiscal balance because higher growth rates signal booms and hence a positive fiscal balance while low growth rates signal downturns and hence a negative fiscal balance. Inflation is measured by changes in the consumer price index and we expect inflation to have negative effect on fiscal balance. This is because, inflation heightens public expenditure and leads to fiscal deficits. Unemployment is measured by the unemployment rate as a percentage of the total labor force-modeled International Labour Organisation (ILO) estimate. We expect high unemployment rate to have negative effect on fiscal balance because it translates to low tax revenue and high social spending such as unemployment benefits. Real interest rate and its lag are expected to translate into high interest rate on debt payments, high borrowing cost and so high fiscal deficit. Debt ratio is proxied by external debt as a percentage of gross domestic product and it is expected to be a priori indeterminate. It can contribute to a reduced fiscal balance because of the statutory annual interest and principal repayments when it is negative. When it takes a positive value, it implies that there is pressure on government to improve their fiscal balance and hence a reduction in discretionary spending. Thus, higher debt levels can induce a fiscal stabilization reaction.

A dummy was created for elections with “1” representing election year and 0 otherwise. Conflict is also a dummy where “1” represents a country that experienced civil war within a given year and 0 otherwise. We expect a negative relations for both elections and conflicts with fiscal balance. Also, u_i , θ_i , ψ_i , ϕ_i and η_i represent country fixed effects, while u_t , θ_t , ψ_t , ϕ_t and η_t represent the time fixed effects. Finally, ε_{it} , γ_{it} , ϖ_{it} , τ_{it} and λ_{it} are the idiosyncratic error terms.

Data sources and scope

This study deploys panel dataset and the sample period covers 1990–2017. The sample includes 52 African countries shown in “Appendix 2”. The data on overall fiscal balance are sourced from International Financial Statistics (IFS) of the International Monetary Fund (IMF) and African Development Bank (AFDB) Socio Economic database while the data on Temperature change anomaly is obtained from the Food and Agriculture Organisation (FAO) of the United Nations. The data on weather events are sourced from the Emergency Events database (EM-DAT) maintained by the Center for Research on the Epidemiology of Disasters (CRED) at the School of Public Health at the University of Louvain, Brussels, Belgium. The data on elections is sourced from a study by Agbloyor (2019) and updated accordingly from internet sources. In like manner, the data on conflicts is sourced from the study by Collier et al. (2008) and also the Center for Systemic Peace, Uppsala Conflict Data Program. The rest of the data including GDP growth rate, real interest rate,

inflation, unemployment and debt ratio are all gleaned from World Bank's World Development Indicators (WDI).

Estimation technique

The main empirical strategy employed in this study is the dynamic two-step system generalized method of moments (GMM) estimation approach with robust standard errors. This choice is motivated by four reasons in conformity with recent GMM-centric literature (see Asongu et al. 2019; Tchamyou et al. 2019; Agoba et al. 2019). First, the cross sectional units (N) are higher than the time series (T). Thus, the number of countries are 52 while the sampled period is 28 years. Secondly, the dataset is panel in nature and the empirical approach accounts for cross country differences in the estimation process. Thirdly, inherent endogeneity concerns are addressed in two ways; GMM controls for unobserved heterogeneity by accounting for time-invariant omitted variables. Also, GMM generates internal instruments that account for simultaneity bias or reverse causality. The robustness of GMM is evidenced in several tests. The Hansen test for over identifying restrictions tests for the validity of the moment conditions. Also, the test of the null hypothesis of no second-order serial correlation is performed by the Arellano–Bond test for autocorrelation (AR (2)). In addition, we use the fixed-effects and random-effects estimation techniques as robustness checks.

Identification, simultaneity and exclusion restriction

It is essential and key to make some few but imperative comments in relation to identification, simultaneity and exclusion restriction when using the GMM estimation technique to ensure a robust model specification. Identification refers to the definitions assigned to the variables involved in the specification exercise which include the outcome variable, endogenous variables and the strictly exogenous variables. In line with contemporary GMM-centric literature, all explanatory variables are considered as endogenous while years are considered to be exogenous. It is worth noting that the explanatory variables consist of the independent variables (temperature change and weather events) as well as the set of control variables (real GDP growth rate, inflation, unemployment, real interest rate, debt ratio, elections and conflicts). In line with the identification process, the exclusion restriction assumption is such that the strictly exogenous indicator influences the outcome variable (fiscal balance) exclusively through the predetermined channels or exogenous components of the independent variables of interest. This assumption underpinning the identification process is consistent with contemporary GMM-centric literature (see Asongu et al. 2020; Tchamyou et al. 2019; Tchamyou and Asongu 2017).

Simultaneity issues relating to reverse causality are taken on board through instrumental variables that are forward differenced. This process involves using Helmert transformations to eliminate fixed impacts that are susceptible to biasing estimated coefficients owing to a correlation between the lagged outcome variable and fixed effects (Asongu et al. 2020). These transformations permit orthogonal or parallel conditions between lagged and forward differenced observations.

Lastly, the assumption of exclusion restriction is investigated with the Difference in Hansen Test for the exogeneity of instruments. The null hypothesis of the underlying test should not be rejected because it is the position that the identified strictly exogenous variables influence the Fiscal balance exclusively via the engaged predetermined variables. This

criterion for validating exclusion restrictions is not very different from traditional instrumental variable approaches that are established on the basis that the null hypothesis of the Sargan/Hansen test should not be rejected in order for the exclusion restriction assumption to hold (Asongu et al. 2020).

Findings

Summary statistics and correlation matrix

This section presents the results of the study starting with a brief discussion of the summary statistics, the correlation matrix, the findings and their implications. The descriptive statistics which gives a general overview of the variables used in the study can be found in Table 1. The response variable, fiscal balance, has a mean of -2.5 percent suggesting that most countries in Africa run on budget deficit. Temperature change anomaly has a mean of 0.70 implying that, on average, the African climate is getting warmer by 0.70 degree Celsius annually. Weather Event 1 has a 93 percent probability of occurring within a year in an African country. Also, Weather Event 2 and Weather Event 3 on average have a probability of occurring approximately 30 percent and 73 percent of the time, respectively. The frequency of weather events over the sample period considered is more pronounced in East Africa than the rest of the African continent. The frequency of weather events in East Africa is 80 percent compared to 48 percent in Central Africa, 51 percent in West Africa and 57 percent in Sub-Saharan Africa.

Table 1 Descriptive statistics

Variable	Obs	Mean	SD	Min	Max
Weather Event 1	1456	0.931	1.229	0	9
Weather Event 2	1456	0.296	0.58	0	5
Weather Event 3	1456	0.725	0.994	0	8
Temperature change	1279	0.70192	0.4054	-0.726	2.39
Fiscal balance	1270	-2.522	4.742	-18.073	20.482
Conflict	1407	0.104	0.306	0	1
Elections	1423	0.182	0.386	0	1
Inflation	1233	8.52	11.288	-11.686	98.224
GDP growth	1390	4.225	8.048	-62.076	149.973
Unemployment	1377	9.299	7.593	0.285	37.94
Real interest rate	869	10.461	49.649	-93.513	1158.026
Debt ratio	1289	69.562	63.051	0.278	485.668
Institutions	988	-0.628	0.588	-2.1	0.88
Control of corruption	988	-0.603	0.6	-1.826	1.217
Gov't Effectiveness	987	-0.707	0.599	-1.89	1.049
Political stability	988	-0.506	0.879	-2.845	1.282
Regulatory quality	988	-0.667	0.597	-2.298	1.127
Rule of law	988	-0.662	0.622	-2.13	1.077
Voice and Account'	988	-0.622	0.724	-2.226	1.007
Adaptation index	1173	37.236	6.3578	25.238	55.918

We further tabulate the frequency of occurrence of weather events in Africa in order to get a detailed and perhaps a more meaningful interpretation of the results as shown in Table 2. Out of a total of 1456 outcomes, Weather Event 1 has occurred 53 percent of the time for at least once in a year. Out of these occurrences, Weather Event 1 has occurred 82% of the time for at least once or twice in a year and the remaining 18% have occurred between three to nine times. Weather Event 2 has occurred just 25 percent of the time and this has been the least occurrence of the three classifications of weather events in Africa. Also, Weather Event 3 has occurred 47 percent of the time with at least one or two counts occurring 88 percent of the time.

Most African countries have weak institutions as shown by the average of institutions. The mean for institutions is -0.628 for a range of -2.5 to 2.5 and lower values depicting weak institutions. The frequency of the occurrence of conflicts and elections in Africa are 10.4 percent and 18.2 percent, respectively. The mean debt ratio in Africa is 69.6 percent which implies that most African countries have high debt ratio and this may have grave implications for fiscal policy particularly limiting the fiscal space. The mean for inflation is 8.52 percent, and that of real interest rate is 10.46 percent. GDP growth rate recorded a mean of 4.2 percent while the average unemployment rate for the sample in Africa is 9.3%. Finally, in terms of adaptation to climatic variabilities, the average adaptation index (ND-GAIN) is 37.2 implying that most African countries have weak adaptive capacity to climate change. The correlation matrix is presented in Table 3. This indicates the correlation between the variables used in the model and shows the basis for any multicollinearity. There are no concerns for multicollinearity.

Result of the effects of temperature change and weather events on fiscal balance

The results of the effects of temperature change and weather events on fiscal balance is presented in Table 4. The results reveal that temperature change anomaly has a negative and statistically significant effect on fiscal balance. As shown in Model 1, increases in average temperature in a meteorological year by a degree Celsius worsens the fiscal balance by 1.097 percentage points. Thus, increases in annual average temperature which implies a

Table 2 Weather events tabulation from 1990–2017. *Source:* Authors construct (2020) from EM-DAT data

Weather Event 1			Weather Event 2			Weather Event 3		
Variable count	Frequency	Percent	Count	Frequency	Percent	Count	Frequency	Percent
0	689	47.32	0	1099	75.48	0	774	53.16
1	435	29.88	1	298	20.47	1	438	30.08
2	191	13.12	2	47	3.23	2	162	11.13
3	76	5.22	3	10	0.69	3	52	3.57
4	36	2.47	4	1	0.07	4	17	1.17
5	18	1.24	5	1	0.07	5	11	0.76
6	5	0.34	6	–	–	6	1	0.07
7	2	0.14	7	–	–	7	–	–
8	3	0.21	8	–	–	8	1	0.07
9	1	0.07	9	–	–	9	–	–
Total	1456	100	Total	1456	100	Total	1456	100

Table 3 Correlation matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) Fiscal balance	1.000									
(2) Weather Events	0.017	1.000								
(3) Conflict	-0.059	0.054	1.000							
(4) Elections	-0.055	-0.023	-0.047	1.000						
(5) Inflation	-0.139	0.052	0.150	-0.037	1.000					
(6) GDP growth	0.206	0.017	-0.125	0.005	-0.042	1.000				
(7) Unemployment	0.158	-0.039	-0.061	0.018	0.026	0.018	1.000			
(8) Real interest rate	-0.011	0.013	-0.044	-0.006	-0.193	-0.043	-0.089	1.000		
(9) Debt ratio	-0.098	-0.141	0.203	-0.035	0.263	-0.134	-0.055	0.044	1.000	
(10) Institutions	-0.062	-0.045	-0.308	0.036	-0.117	0.075	0.318	-0.134	-0.171	1.000

Table 4 The effects of temperature change and weather events on fiscal balance

Variables	Model 1	Model 2	Model 3	Model 4
Lag of fiscal balance	0.388*** (0.111)	0.397*** (0.102)	0.401*** (0.102)	0.397*** (0.103)
Temperature change	− 1.097** (0.496)	−	−	−
Weather Event 1	−	0.017 (0.142)	−	−
Weather Event 2	−	−	− 0.444* (0.219)	−
Weather Event 3	−	−	−	0.001 (0.134)
Conflict	− 0.062 (0.400)	0.141 (0.359)	0.152 (0.337)	0.147 (0.352)
Elections	− 0.458 (0.357)	− 0.521 (0.310)	− 0.560* (0.318)	− 0.522 (0.312)
Inflation	− 0.022 (0.015)	− 0.015 (0.013)	− 0.014 (0.013)	− 0.015 (0.013)
GDP growth rate	0.205*** (0.049)	0.203*** (0.047)	0.203*** (0.045)	0.204*** (0.047)
Unemployment rate	0.062** (0.025)	0.071*** (0.020)	0.067*** (0.020)	0.071*** (0.020)
Lag of real interest rate	0.017 (0.014)	0.011 (0.013)	0.012 (0.012)	0.011 (0.013)
Lag of debt ratio	0.008*** (0.002)	0.008*** (0.003)	0.008*** (0.002)	0.008*** (0.002)
Constant	− 1.682*** (0.564)	− 2.704*** (0.477)	− 2.461*** (0.463)	− 2.681*** (0.490)
Observations	489	563	563	563
Number of countries	27	30	30	30
Number of instruments	11	11	11	11
Wald test (Prob > F)	0.000	0.000	0.000	0.000
AR(1):(Pr > z)	− 2.40(0.016)	− 2.59(0.009)	− 2.61(0.009)	− 2.59(0.010)
AR(2):(Pr > z)	0.56(0.578)	0.47(0.641)	0.44(0.663)	0.46(0.645)
Sargan test:(Prob > chi2)	0.26(0.610)	0.04(0.833)	0.08(0.771)	0.05(0.824)
Hansen test: (Prob > chi2)	0.16(0.690)	0.02(0.884)	0.04(0.843)	0.02(0.878)

Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ Model 1 addresses the effects of temperature change on fiscal balance. Model 2, Model 3 and Model 4 address the effects of Weather Event 1, Weather Event 2 and Weather Event 3 on fiscal balance

warmer climate worsens the fiscal balance in Africa by specifically contributing to a higher fiscal deficit. We find no statistically significant effects of Weather Event 1 (small-scale event) and Weather Event 3 (medium-scale event) on fiscal balance as shown in Model 2 and Model 4, respectively. However, Weather Event 2 (large-scale or extreme weather events) has a negative and statistically significant effect on fiscal balance as shown in Model 3. The occurrence of Weather Event 2 causes an increase in fiscal deficit by 0.444

percentage points. This implies that for a weather-related event to exert a significant impact on fiscal balance in Africa, it needs to be large and consequential enough causing severe damage to persons, properties and resulting in thousands of deaths. And this leads to large sums of money being spent on relief items and reconstruction of affected areas and damaged infrastructure. This may be a contributing factor toward the fiscal deficits experienced in some African countries in recent years. This result is similar to the findings by Lis and Nickel (2010) in developing countries where extreme weather events have negative fiscal impact.

The reasons why climate change and extreme weather events may worsen fiscal balance may be due to the high cost of adaptation and mitigation including but not limited to capital investments and annual budgetary allocations to climate sensitive sectors. Specifically, some itemized expenditure in the budgets of African countries include; cost of building institutional capacity to plan and manage climate change, including early warning and monitoring by the meteorological services; physical damage to existing infrastructure and hence increased maintenance cost; increased health expenses due to climate sensitive diseases; extra cost of climate proofing infrastructure and cost of tree planting exercises and forest conservation. The cost of adaptation may range between \$20–\$30 billion dollars per annum (see Mekonnen 2014).

The growth rate in Gross Domestic Product (GDP) shows a significant positive effect on fiscal balance in all our models (Model 1–Model 4). Thus, growth in GDP improves the fiscal balance and implies that during booms, fiscal deficit in Africa reduces. This is because all things being equal, booms are directly accompanied with higher tax revenues hence creating more fiscal space for African governments. This corroborates the findings of Lis and Nickel (2010) for developing countries, EU countries as well as OECD countries. It is also in line with the findings of Tujula and Wolswijk (2007).

Inflation generally has no statistical significance in our main models (Model 1–Model 4). However, when it appears significant in Model 10–Model 12, it comes with a negative sign. Thus, increases in the consumer price level leads to fiscal deficit in Africa. This is because increases in price level heightens expenditure and also causes a reduction in real tax revenue. It can also lead to a rise in interest rate, hence worsening fiscal balance. This finding rather contradicts the findings of Lis and Nickel (2010) who found a positive relationship with budget balances in the full sample and for developing countries.

Elections also has a negative and statistically significant effect on fiscal balance in Model 3. This reflects political business cycles where most African governments undertake excessive spending during presidential and parliamentary elections years hence causing fiscal deficits.

We find unemployment to have a positive and significant effect on fiscal balance even though we expected an inverse relationship. Conversely, high levels of unemployment could imply less expenditure on wage bills which forms a significant chunk of African government annual expenditure and hence a positive outlook for fiscal balance. In addition, IMF conditionality for securing a bailout for most African countries require a tightening of fiscal balance and strict adherence to fiscal discipline measures particularly a cut in employment which usually leads to an improvement in fiscal balance. Also, payments for unemployment benefits may not be a frequent phenomenon in Africa and hence less fiscal implications.

Last but not the least, previous year debt ratio has a positive and significant effect on fiscal balance. This means that previous year debt signal to government of a limited fiscal space and the need to be cautious about spending in subsequent periods. This finding is consistent with those of Tujula and Wolswijk (2007); Lis and Nickel (2010) who argue

that countries with high debt ratios commerce consolidation efforts to reduce this burden and hence creating an improved fiscal balance. We find no statistically significant effect of conflict and lag of real interest rate on fiscal balance in our sample of African countries. These results are robust to fixed-effects and random-effects estimations shown in Model 13–Model 16 in “Appendix 1”.

The moderating roles of institutions and adaptive capacity on fiscal balance

Generally, institutions remain weak in Africa and this is evidenced in the mean of institutions as shown in Table 1. Our findings reveal that African countries that have relatively strong institutions are more resilient to extreme weather events and temperature change anomalies. Conversely, countries with weak and underdeveloped institutions have low resilience to climate change impacts. This can be seen in the interactive effect of Weather Event 2 and institutions and more importantly in the net negative effect (-0.0225) shown in Model 5 in Table 5. Thus, the impact of extreme weather events on fiscal balance is less severe when institutions are relatively strong (-0.0225) than when they are weak (-0.832). This result is robust to fixed-effects estimates as shown in Model 17 in “Appendix 1”. The implication of this finding is that the fiscal consolidation efforts of some African governments may be thwarted as extreme weather events are considered as external shocks in countries with weak institutions. In the same vein, the impact of temperature change anomaly on fiscal balance is less severe when institutions are relatively strong as shown by the net negative effect (-1.1698) than when they are weak (-2.173) as shown in Model 10 in Table 6. It is worth mentioning that the negative synergy between weather event and institution is apparent because both the unconditional and conditional effects used in the computation of the net impact are negative and this is consistent with contemporary interactive regressions literature (Asongu and Nwachukwu 2017; Asongu and Acha-Anyi 2019).

In addition, we interact the various components of institutions with extreme weather event (Weather Event 2) and temperature change shown in Tables 5 and 6, respectively. The findings show that African countries that have more effective governments, quality regulations and stringent voice and accountability mechanisms experience less impacts of extreme weather events than those that do not. This can be observed in the negative net effects of -0.0434 , -0.0196 and -0.0391 in Model 6, Model 7 and Model 8, respectively, in Table 5. Similarly, African countries that have put in systems to control corruption and are more effective with the practice of rule of law experience less impacts of temperature change anomaly than those that do not. This can be observed in the negative net effects of -1.1043 and -1.050 in Model 11 and Model 12, respectively, in Table 6. Barisik and Baris (2017) similarly find statistically significant effects of voice and accountability, regulatory quality and political stability on budget balances in developing countries. The general implication of these findings is that African countries that have weak governance structures may be severely hit by extreme weather events and climate change impacts.

Similarly, most African countries have low adaptive capacities with the exception of Mauritius, Morocco and South Africa which have average adaptive index scores. African countries with relatively strong adaptive capacities may experience less impact of extreme weather events. This is evidenced in the negative interactive effect (-0.800) of Weather Event 2 and adaptive capacity and shown in Model 9 in Table 5. This means that countries with weak systems and structures may have late warning systems which has severe

Table 5 The moderating role of institutional variables and adaptive capacity—Weather Event 2

Variables	Model 5	Model 6	Model 7	Model 8	Model 9
Lag of fiscal balance	0.519*** (0.109)	0.521*** (0.103)	0.518*** (0.098)	0.502*** (0.106)	0.421*** (0.084)
Weather Event 2	− 0.832** (0.361)	− 0.843** (0.364)	− 0.756*** (0.265)	− 0.579* (0.286)	− 0.272 (0.256)
Institutions	− 0.399 (0.614)	−	−	−	−
Event 2—Institutions	− 1.289* (0.680)	−	−	−	−
Gov't Effectiveness	−	− 0.448 (0.504)	−	−	−
Event 2—Gov't effect'	−	− 1.131* (0.592)	−	−	−
Regulatory quality	−	−	0.093 (0.643)	−	−
Event 2—Reg' Quality	−	−	− 1.104* (0.569)	−	−
Voice and Accountability	−	−	−	− 0.382 (0.457)	−
Event 2—Voice and Acct'	−	−	−	− 0.868* (0.440)	−
Adaptation index	−	−	−	−	− 0.249 (0.423)
Event 2—Adapt' Index	−	−	−	−	− 0.800* (0.466)
Conflict	0.382 (0.618)	0.451 (0.539)	0.595 (0.543)	0.355 (0.518)	0.038 (0.358)
Elections	− 0.638 (0.518)	− 0.630 (0.511)	− 0.685 (0.514)	− 0.624 (0.505)	− 0.545 (0.328)
Inflation	− 0.024 (0.016)	− 0.019 (0.017)	− 0.020 (0.017)	− 0.024 (0.015)	− 0.010 (0.012)
GDP growth rate	0.180** (0.068)	0.188*** (0.067)	0.184** (0.068)	0.184*** (0.066)	0.196*** (0.045)
Unemployment	0.093*** (0.021)	0.093*** (0.023)	0.079*** (0.019)	0.087*** (0.019)	0.085*** (0.023)
Lag of real interest	0.017 (0.017)	0.013 (0.016)	0.016 (0.017)	0.014 (0.017)	0.011 (0.011)
Lag of debt ratio	0.007*** (0.002)	0.007*** (0.002)	0.008*** (0.003)	0.008*** (0.002)	0.007*** (0.002)
Constant	− 2.762*** (0.614)	− 2.798*** (0.605)	− 2.367*** (0.648)	− 2.676*** (0.577)	− 2.371*** (0.425)
Net effects	− 0.023	− 0.043	− 0.019	− 0.039	
Observations	445	445	445	445	563
Number of Countries	30	30	30	30	30
Number of Instruments	14	14	14	14	14

Table 5 (continued)

Variables	Model 5	Model 6	Model 7	Model 8	Model 9
Wald test	0.000	0.000	0.000	0.000	0.000
AR(1):(Pr > z)	(0.014)	(0.014)	(0.013)	(0.013)	(0.006)
AR(2):(Pr > z)	(0.200)	(0.195)	(0.204)	(0.207)	(0.638)
Sargan test	(0.187)	(0.206)	(0.153)	(0.197)	(0.659)
Hansen test	(0.187)	(0.206)	(0.223)	(0.253)	(0.739)

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

Model 5 contains the interaction of Weather Event 2 and Institutions. Model 6, Model 7 and Model 8 contain the interaction of Weather Event 2 with government effectiveness, regulatory quality and voice and accountability, respectively. Model 9 contains the interaction of Weather Event 2 with adaptive capacity

consequences for fiscal balance and fiscal policy formulation through higher post-disaster relief expenditure and lower tax revenue from productivity losses.

Conclusion, policy recommendations and directions for future studies

Climate change remains a threat to the globe and this has necessitated the gathering of leaders from all over the world. The main points of discussion at these gatherings are to brainstorm on measures needed to reduce global carbon emissions and how to raise the needed funds to mitigate future climate occurrence. Finance therefore is always a focal point in these discussions. This paper investigates the impacts of climate change and extreme weather events on fiscal balance and the implications these may have for fiscal policy in Africa. It also investigates how institutions and adaptive capacities moderate the effects of extreme weather event on fiscal balance. Our findings reveal that climate change proxied by temperature change anomaly and extreme weather events deteriorate fiscal balance. Thus, they lead to a hike in fiscal deficits in Africa mainly due to the high cost of adaptation and mitigation as well as the relief payments to surviving victims and loss in tax revenue. We also find African countries with stronger institutions and adaptive capacities to endure less impacts of extreme weather events and temperature change anomalies.

We recommend that African countries should tighten their fiscal consolidation efforts as climate change and weather events may prove to be a destabilizer to these efforts. For example, African governments could create a National Disaster Risk Management Fund in their respective countries where funds are allocated annually purposely for climate change mitigation and not only for adaptation like it is being practiced. This will reduce the future impacts of climate change and extreme weather events on their fiscal space. African governments can do little in isolation on the international climate scene but there appears much more can be done with a concerted effort on the whole. We therefore suggest that African governments should form a coalition with one strong voice in the fight against climate change for much larger funds to be allocated and this should be consistent. They should also lead the charge against carbon emissions worldwide. This is because literature suggest that African countries emit less but bear most of the consequences of climate change. Furthermore, this study adds its voice to the countless list of authors that have requested for African governments to have much stronger institutions. This is because countries that have buoyant and vibrant institutions spend less to adapt to climate change impacts as extreme weather events are considered external shocks in countries with weak institutions and this may destabilize fiscal consolidation efforts.

Table 6 The moderating role of institutional variables on fiscal balance—temperature change

Variables	Model 10	Model 11	Model 12
Lag of fiscal balance	0.484*** (0.100)	0.479*** (0.092)	0.478*** (0.109)
Temperature change	− 2.173*** (0.780)	− 1.934*** (0.690)	− 2.222*** (0.735)
Institutions	0.141 (0.966)	–	–
Temperature change—Institutions	− 1.600* (0.845)	–	–
Control of corruption	–	0.351 (0.757)	–
Temperature—Control of corruption	–	− 1.376** (0.654)	–
Rule of law	–	–	0.066 (0.900)
Temperature—rule of law	–	–	− 1.770** (0.832)
Conflict	− 0.249 (0.569)	− 0.008 (0.530)	− 0.394 (0.492)
Elections	− 0.609 (0.553)	− 0.608 (0.544)	− 0.577 (0.562)
Inflation	− 0.028* (0.014)	− 0.028* (0.015)	− 0.027* (0.014)
GDP growth rate	0.153** (0.060)	0.157** (0.061)	0.153** (0.057)
Unemployment rate	0.079*** (0.027)	0.074** (0.028)	0.084*** (0.023)
Lag of interest	0.015 (0.018)	0.015 (0.018)	0.017 (0.018)
Lag of debt ratio	0.007** (0.003)	0.008*** (0.002)	0.007** (0.003)
Constant	− 1.198 (1.011)	− 1.163 (0.915)	− 1.359 (0.961)
Net effects	− 1.169	− 1.104	− 1.050
Observations	388	388	388
Number of countries	27	27	27
Number of instruments	14	14	14
Wald test (Prob > F)	0.000	0.000	0.000
AR(1):(Pr > z)	− 2.36(0.018)	− 2.38(0.017)	− 2.35(0.019)
AR(2):(Pr > z)	1.34(0.179)	1.37(0.169)	1.37(0.170)
Sargan test:(Prob > chi2)	1.93(0.381)	1.62(0.446)	2.21(0.331)
Hansen test: (Prob > chi2)	2.17(0.338)	1.90(0.387)	2.28(0.319)

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

Model 10 addresses the interaction between Temperature change and Institution

Model 11 addresses the interaction of temperature change with control of corruption

Model 12 addresses the interaction of temperature change and rule of law

Future studies should broaden the time span and consider different indicators of climate change and weather events and their inherent fiscal policy implications for the African continent while juxtaposing that with data and empirical evidence from other continents. Also, future research should include current account, exchange rate as relevant controls besides including internal debt as part of the total debt structure.

Appendix 1: Robustness checks for main results using fixed effects (FE) and random effects (RE)

Variables	Model 13 RE	Model 14 FE	Model 15 RE	Model 16 FE	Model 17 FE
Weather Event 2			– 0.443** (0.219)	– 0.384* (0.212)	– 1.133** (0.423)
Temperature change	– 1.654*** (0.441)	– 1.682*** (0.461)			
Institutions					0.430 (1.832)
Weather Event 2—institutions					– 1.222* (0.683)
Conflict	– 0.406 (0.541)	– 0.861 (0.743)	0.0893 (0.536)	– 0.133 (0.700)	– 0.255 (0.833)
Elections	– 0.672* (0.359)	– 0.617* (0.360)	– 0.744** (0.326)	– 0.718** (0.327)	– 0.689 (0.437)
Inflation	– 0.0595*** (0.0207)	– 0.0685*** (0.0233)	– 0.0493*** (0.0178)	– 0.0582*** (0.0198)	– 0.0629** (0.0304)
GDP growth rate	0.227*** (0.0638)	0.221*** (0.0653)	0.229*** (0.0555)	0.220*** (0.0572)	0.224** (0.0815)
Unemployment	0.0960** (0.0389)	0.140* (0.0762)	0.0981*** (0.0355)	0.114 (0.0772)	0.169* (0.0944)
Lag of interest rate	0.00314 (0.0253)	0.00177 (0.0267)	– 0.00462 (0.0252)	– 0.00897 (0.0267)	– 0.0167 (0.0336)
Lag of debt ratio	0.0108*** (0.00338)	0.0118*** (0.00360)	0.0115*** (0.00371)	0.0132*** (0.00394)	0.0147*** (0.00384)
Constant	– 1.985*** (0.641)	– 2.450*** (0.864)	– 3.387*** (0.522)	– 3.528*** (0.576)	– 3.824*** (1.161)
Observations	492	492	567	567	448
R-squared	0.1163	0.118	0.0958	0.097	0.110
Number of countries	27	27	30	30	30
Prob > chi2/ Prob > F	0.0000	0.0000	0.0000	0.0000	0.0000

Robust standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ Model 13 and Model 14 show the effects of temperature change on fiscal balance using random effects and fixed effects, respectively. Model 15 and Model 16 show the effect of Weather Event 2 on fiscal balance using random effects and fixed effects, respectively. Model 17 shows the effects of the interaction of Weather Event 2 and Institutions on fiscal balance.

Appendix 2: List of countries used in the study

1. Algeria	2. Angola	3. Benin	4. Botswana	5. Burkina Faso	6. Burundi
7. Cabo Verde	8. Cameroon	9. CAR	10. Chad	11. Comoros	12. DRC
13. Congo Republic	14. Côte D'Ivoire	15. Djibouti	16. Egypt	17. Equatorial Guinea	18. Eritrea
19. Eswatini	20. Ethiopia	21. Gabon	22. Gambia	23. Ghana	24. Guinea
25. Guinea Bissau	26. Kenya	27. Lesotho	28. Liberia	29. Libya	30. Madagascar
31. Malawi	32. Mali	33. Mauritania	34. Mauritius	35. Morocco	36. Mozambique
37. Namibia	38. Niger	39. Nigeria	40. Rwanda	41. Sao Tome and Principe	
42. Senegal	43. Seychelle	44. Sierra Leone	45. South Africa	46. Sudan	47. Tanzania
48. Togo	49. Tunisia	50. Uganda	51. Zambia	52. Zimbabwe	

Funding No Funding was received to assist with the preparation of this manuscript.

Declaration

Conflict of Interest The authors declare that they have no conflict of Interest.

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