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FISCAL & MONETARY POLICIES, CLIMATE CHANGE AND INCOME INEQUALITY IN AFRICA

BY

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DECLARATION

I hereby declare that this thesis is my original work produced from research I carried out under supervision. This thesis has not been presented by anyone for any academic award, in this or any other institution. All references made to works done have been duly acknowledged. I am solely responsible for any shortcomings in this work.

.... 23/12/22 ....

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CERTIFICATION

I hereby certify that this work was done and supervised in accordance with laid down regulations of the University of Ghana.

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DEDICATION

I dedicate this thesis to my late dad, Fred Komla Kunawotor. I am still a beneficiary of your prayers and sacrifices while you were here on earth. May you continue to enjoy eternal rest in the bosom of the Lord. I also dedicate this thesis to my wife, Hannah Tieku-Kunawotor and two lovely kids, Marc Kayden Edem Kunawotor and Kimberly Kekeli Kunawotor.

ABSTRACT

This study is an essay on fiscal policy, monetary policy, climate change and income inequality in Africa. The study covers 52 African countries over the period 1990 – 2017.

The aim of the first empirical paper is to investigate the effects of temperature change and extreme weather events on fiscal balance in Africa and their implications for fiscal policy formulation. It also investigates the extent to which institutions and adaptive capacity moderate the impacts of extreme weather events and temperature change on fiscal balance. This paper uses the System Generalized Method of Moments, Fixed Effects and Random Effects estimation strategies. The results show that temperature change anomaly which implies a warmer climate in a meteorological year worsens fiscal balance in Africa. The findings also reveal that weather-related events may have a significant negative impact on fiscal balance, if the damage caused is large and consequential. Furthermore, African countries that have relatively strong institutions and adaptive capacities tend to moderate the impact of temperature change anomaly and extreme weather events on fiscal balance. The policy implications of this paper is that the frequent incidence of climatic disruptions and extreme weather events which are considered external shocks, may make the fiscal consolidation efforts and debt sustainability measures of some African governments a little more difficult.

The second empirical paper examines the direct effect of extreme weather events on headline inflation and food price inflation. It further investigates if agricultural production empirically serves as a conduit through which extreme weather events impact inflation. This paper uses a two-step system Generalized Method of Moments estimation technique with robust standard errors and Panel VECM and finds that weather-related events may need to occur on a large scale or be extreme to cause a significant price hike in Africa. There is also a bi-directional causality

between inflation and extreme weather events in the long run. It also finds that the incidence of droughts and floods leads to a rise in food price inflation. Furthermore, the results reveal that agricultural production serves as a perfect mediator through which extreme weather events affect headline inflation. The policy implication of this paper is that monetary policy authorities may need to consider the implications of supply shocks caused by extreme weather events on general price levels. Also, anchoring inflation expectations should be a drive of policy makers as both headline inflation and food inflation appear quite persistent in Africa.

The third empirical paper investigates the effects of weather events and the various types, on income inequality in Africa. It also investigates the impacts that institutions and adaptive capacity play in moderating the impact of weather events on income inequality. Furthermore, it investigates if agricultural productivity mediates the impacts that weather events has on income inequality. The findings using the difference Generalized Method of Moments estimator reveal a non-monotonic U-shape relationship between weather events and income inequality. The result using a simultaneous quantile regression approach shows that weather events increase income inequality at the 10th, 25th, 50th and 75th percent quantiles. In terms of the weather events types, the paper also finds a non-monotonic U-shape relationship between flood and income inequality. Furthermore, institutions tend to moderate the impacts weather events has on income inequality. The results however, shows that there is no statistically significant mediating role of agricultural productivity on the weather events and income inequality nexus. Again, the result appears statistically insignificant on the moderating role adaptive capacity plays in the weather – income inequality nexus. The policy implication is that income inequality concerns should not be ignored in the global climate change discussions. Also, African countries need to strengthen their institutions and adaptive capacities as they remain very weak in the continent.

The fourth and final empirical paper examines the distributional effects of both fiscal and monetary policies in Africa. This paper deploys the two-step dynamic system GMM, the simultaneous quantile regression technique and Panel VAR and also uses variants of fiscal and monetary indicators including fiscal redistribution. The results show that fiscal redistribution has been quite effective in Africa as reflected in the role played by income taxes and transfers in reducing Gini coefficients albeit to a relatively little extent. The result shows that direct tax is progressive and a potent tool in redistributing income in favour of the have-nots while indirect tax unsurprisingly is regressive and income un-equalizing. Similarly, the paper finds property taxes to have income un-equalizing effects in Africa. The results of the expenditure indicators reveal that government spending on basic and primary education narrows net income inequality while government spending on secondary and tertiary education rather widens net income inequality. Also, the result show that contractionary monetary policy has unintended distributional effects in Africa. The policy implication of this paper is that African governments need to broaden their tax net, increase the share of direct tax including property tax in the tax net and spend more on basic education to improve income distribution in Africa.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Climate change has gained global recognition with heightened concerns by governments, policy makers and households. The persistent worsening of the climate system through human activities is popularly termed as anthropogenic global warming or climate change. The World Meteorological Organisation defines climate change to encompass all forms of climatic variability on time scale that spans over a decade and can be observed through changes in the average weather patterns worldwide. Climate change has caused melting of glaziers, sea level rises, changes in wind movements, heatwaves, floods, droughts, hurricanes and tsunamis. The reality of climate change on the African continent can be seen in the various regions according to the report of the Centre for International Governance Innovation (2009). The report notes that there are prolonged and intensified droughts among the Eastern African countries, flooding observed in West Africa, rainforest depletion in equatorial Africa and increasingly intensified ocean acidity in Southern Africa.

Climate change is of global concern due to its linkage with the occurrence of several extreme weather events and natural disasters. For example, available evidence (see, Kireyev, 2018; Stott, 2016; Stott et al., 2016) indicate that the severity and frequency of extreme weather events is due to climate change or global warming. Weather events as captured by the Emergency Events Database (EM-DAT) are a special type of natural disasters that are climatological, meteorological or hydrological and may require the happening of at least one of the following; 10 or more people killed, 100 or more people affected or injured, a declaration of a state of emergency by the affected country and/or a call for international assistance. The Global climate

Risk Index (2017) reports that more than half a million people have died due to 11 thousand extreme weather events between 1996 and 2015. Extreme weather events thus have had marked repercussions for global economic activities and have caused several damages to properties as well as injuries and death of persons. Climate change has derailed economic performance in many countries (IMF, 2017; Mendelsohn, 2013; Dell et al., 2012). It is particularly a destabilizer to the economic progress made in African countries in the midst of wide-spread poverty (Cashin et al., 2017; Hallegatte et al., 2016). Climate change and weather events pose a challenge to public finances due to the unexpected government spending to fix infrastructure damages and cater for injured persons (see, Bachner et al., 2019; Melecky & Raddatz, 2015; Ouattara & Strobl, 2013; Lis & Nickel, 2010). There is also a reduced revenue flow due to the devastating impacts on income generating essential national assets.

Besides the high costs to adapt to climate change impacts (Mekonnen, 2014), government spends millions of dollars to mitigate future climate variabilities and this affects annual budgetary allocation (Bird et al., 2016). This situation even appears worse in African countries due to the existing high fiscal deficits and debt stocks coupled with limited fiscal space and poor fiscal management. A recent report by the African Development Bank (2021) reveals that the weight of climate-related expenditure for some African countries reaches up to 10 percent of their national budgets. This hinders the development of these nations as resources are shifted from key sectors such as health, education and infrastructure in order to spend on climate change adaptation and resilience.

Africa's growth and development prospects may also be impaired because the high and persistent levels of economic inequality in Africa (Kunawotor et al., 2020; Asongu et al., 2020; UNDESA, 2019) may further deteriorate due to climate change impacts. This is because a lot of people depend on climate sensitive agriculture for survival and livelihood (UNDP, 2014). Thus, climate change poses a threat to many low-income earners in Africa and this may further widen the economic gap. Food prices according to FAO (2017) is also projected to rise by about 12 percent by 2030 in Africa due to the impacts of climate change and weather events. This may affect the price stability function of central banks and thence monetary policy formulation. Central banks are therefore being advised to pay attention to climate change and climate related policies as these external shocks could affect their financial and monetary stability targets. Particularly, weather events such as droughts, flood, storms and sea-level rises may cause inflationary pressures due the decline in goods or productivity shocks (Batten, 2018). This study addresses two main concerns. First, it addresses the implications climate change and weather-related events have for income inequality, fiscal policy and monetary policy in Africa. Secondly, it discusses the distributional effects of both fiscal and monetary policies in Africa.

1.2 Problem Statement & Research Questions

Climate change and weather events have become global threats and they affect all countries to some extent. The scale of climate change impacts vary by geographical and socioeconomic conditions (Dasgupta, Emmerling & Shayegh, 2020). African countries, however, are more vulnerable to climate change impacts than any other continent (Farid et al., 2016; Lanzafame, 2014; World Bank, 2014), because most African countries have put in place less defense systems against the brunt of climate change and weather events. This is evident in the preparedness levels of these countries towards climatic variabilities and reflects in the Notre Dame Global Adaptation Index (ND-GAIN). In the ND-GAIN (2018) ranking of countries that summarizes a countries vulnerability to climate change and other global challenges in combination with their readiness to improve resilience, the top 5 spots unsurprisingly are occupied by Norway, New

Zealand, Finland, Denmark and Sweden in a descending order. On the other hand, the bottom 5 spots are occupied by African countries such as Democratic Republic of Congo, Eritrea, Central African Republic, Somalia and Chad in a descending order. In Africa, only Mauritius, Morocco and Tunisia had scores slightly above 50 out of 100, with the other countries scoring below the average.

Due to the severe impacts of climate change on the developing world such as African countries, Feyen, Utz, Huertas, Bogdan and Moon (2020) argue that climate change poses a greater risk to global poverty reduction and to the achievements of the sustainable development goals. This is quite an alarming situation because a lot of studies also show evidence that climate change and weather events have repercussions for economic growth and macroeconomic performance (Alagidede et al., 2014; Cavallo & Cavallo, 2014; Klomp &Valckx, 2014; Cavallo & Noy, 2011; Dell et al., 2009). Some other studies show that climate change reduces welfare (Donadelli et al., 2017) and increases income inequality both within and between communities (Hsiang et al., 2019).

Climate change can have fiscal consequences as it tends to increase government spending and reduce revenue. Most African countries already have limited fiscal space due to low tax efforts and high public expenditure. Climate change and weather events hence have dire implications for Africa's limited fiscal space due to the damage and destruction of human life, properties, crops and livestock. For example, about 51,569 people have been killed and 412 million people adversely affected due to 1,381 different forms of weather events between 1990 and 2019 in Africa according to the Center for Research on the Epidemiology of Disasters. This has led to a total damage cost of over US$ 19.78 billion to property, crops and livestock and has grave financial implications and debt sustainability issues. More threateningly, the United Nations

Climate Change (2018) argues that, debt payments will increase by $168 billion over the next decade in countries that are more vulnerable to climate change. Empirical evidence (see, Bachner et al., 2019; Melecky and Raddatz, 2015; Noy and Nualsri, 2011; Lis and Nickel, 2010) points out that natural disasters and extreme weather events can have serious issues for public finances and budget balances. This raises questions for the implications of climate change and weather-related events for Africa's fiscal balance and fiscal policy formulation.

Besides the fiscal side, empirical evidence on the implications of climate change and weather events for monetary policy is relatively nascent. The reason for the limited number of empirical studies is that climate change issues are considered externalities which are best solved through the tools of fiscal policy. Further, climate change has long term impacts while monetary policy largely focuses on price stability in the short term and hence there appears to be a mismatch.

Recent studies (see, Economides and Xepapadeas, 2018; Annicchiarico and Di Dio, 2017), however, argue that central banks may have a role to play as monetary policy may be affected. For example, food prices in Africa may be affected through the external shocks caused by climate change to agricultural productivity. This may be due to the climate sensitive nature of agriculture production in Africa and also the extent of over reliance on agriculture as a source of livelihood (UNDP, 2014). These external shocks in the form of climate change and weather events may therefore affect general price levels and this may have implications for the setting of monetary policy rate. Consequently, this study in addition to the fiscal implications, also examines the implications of climate change for inflation and monetary policy in Africa.

Another concern in this study is the consequences of climate change impacts on income inequality. This concern is premised on the evidence that African countries have the highest income inequality world-wide, falling just behind Latin America and the Caribbean (UNDESA, 2019). UNDP (2017) also indicates that ten out of the world's nineteen most unequal countries are found in Africa. Further, income inequality is very persistent in Africa (Shimeles & Nabassaga, 2018; Odusola, 2017). More intriguingly, income inequality is of concern in this study because high and persistent levels of income inequality have ramifications for economic growth and poverty reduction (OECD, 2015; Ostry, Berg, & Tsangarides, 2014; IMF, 2014). This notwithstanding, studies by UNDESA (2020); Dasgupta et al. (2020); Otrachshenko and Popova (2019), and Diffenbaugh and Burke (2019) show that climate change and weather events worsen inequality. However, little comprehensive evidence exists on the impact of weather events and the various types on within-country income inequality in Africa.

Fiscal policy is the primary tool used for income redistribution. It has been more useful in advanced economies than in developing countries due to the low tax efforts in developing economies (Gupta, 2018). Although fiscal policy has been widely acknowledged as the potent tool in addressing income inequality, there are few empirical studies in Africa to back this assertion and this falls in line with the thought of Odusola (2017). This study delves into the distributional effects of fiscal policy with a particular focus on African countries where empirical evidence appears scarce. The study in addition, focuses on the unintended potential distributional effects of monetary policy in Africa. This is because, besides the potency of fiscal policy in income redistribution, recent empirical evidence in advanced countries (see, Furceri et al., 2018; Coibion et al., 2017; Mumtaz and Theophilopoulou, 2017) are beginning to attribute some potential distributional consequences to monetary policy. The research questions that emanate from the above discussions are;

1. What effects do climate change and extreme weather events have on fiscal balance and what are the implications for fiscal policy formulation in Africa?

2. What are the implications of extreme weather events for inflation and monetary policy formulation in Africa?
3. Do weather events have any effects on income inequality in Africa?
4. To what extent do institutions and adaptive capacity modulate the impacts of weather events and climate change on fiscal balance and income inequality in Africa?
5. What are the distributional effects of fiscal and monetary policies in Africa?

1.3 Research Objectives

1. To investigate the effects of climate change and extreme weather events on fiscal balance and their implications for fiscal policy formulation in Africa.
2. To examine the impacts of extreme weather events on inflation and the implications for monetary policy formulation in Africa.
3. To examine the effects of weather events on income inequality in Africa.
4. To investigate the extent to which institutions and adaptive capacity modulate the impacts of extreme weather events and climate change on fiscal balance and income inequality in Africa.
5. To examine the distributional effects of fiscal and monetary policies in Africa.

1.4 Literature Review

The extant related literature on climate change and fiscal policy has largely focused on how natural disasters such as hurricanes, earthquakes and extreme weather events affect public budget and budget balance and these studies mainly focus on the advanced and middle income countries. These studies fail to take into consideration the effects of temperature change and weather-related events on fiscal balance in developing countries and Africa.

The extant empirical literature on climate change, inflation and monetary policy has focused on the implications climate change, weather shocks and natural disasters have on agricultural output and inflation. Other strands of literature have concentrated on the relevant roles that central banks can play in the fight against climate change and conclude that monetary policy authorities may need to respond to the adverse effects of supply shocks caused by climate change. Most of these studies concentrate on natural disasters in general, such as earthquakes, hurricanes or specific types of weather events such as droughts or floods but not climate change induced-weather events in general. Most studies also fail to consider the direct effects of weather-related events on price level in African countries. Also, there are limited empirical evidences on the channels through which weather events affect inflation.

There is a general high dearth of literature on the relationship between climate change and income inequality. However, a vast amount of literature have focused on why climate change and extreme weather events affect the poor more disproportionately. The few studies that attempt climate change-inequality nexus focused on between-country inequality or climate change measured mostly by temperature. These studies mostly ignore weather events, within-country income inequality and African countries.

The empirical literature on fiscal policy and income inequality largely addresses concerns regarding OECD countries and emerging markets economies. Most of these studies neglect developing countries in Africa in their scope. The few available studies on Africa are either exploratory without providing econometric evidence or centered on individual countries in Africa. Similarly, although the literature on the linkage between monetary policy and inequality is nascent, the few available studies focused on the advanced economies like the USA and UK and emerging market economies with little empirical evidence on African economies.

1.5 Methodology

This study covers the period 1990 – 2017 and broadly includes 52 African countries. The number of countries however, vary per empirical paper premised on the limited data of some key variables in some countries. The list of these countries is shown in Appendix 1. The data is sourced from the World Bank, International Monetary Fund, African Development Bank, Food and Agricultural Organisation of the United Nations, Emergency Events database, Standardized World Income Inequality database, International Centre for Tax and Development and UNU-WIDER government database. The empirical models in this study are mainly multiple regression models which regresses the response variables on outcome variables in addition to some set of control variables. The main outcome variables are fiscal balance, inflation and income inequality. The main independent variables are climate change variables including temperature change, weather-related events, fiscal policy and monetary policy. The estimation strategy deployed in this study are the Fixed Effects, Random Effects, System Generalized Method of Moments, Difference Generalized Method of Moments, Panel Vector Error Correction Model, Panel Vector Autoregressive Model and the Quantile regression techniques. All the necessary diagnostic tests and robustness checks were carried out.

1.6 Significance of the study

There is abundant literature on the implications of climate change for economic performance and the required costs needed to adapt to climate change impacts. Literature, however, on the effects climate change and extreme weather events have on fiscal balance, inflation and income inequality has been in high dearth especially in the African context. The first empirical paper in this study provides new empirical evidence to guide African governments and policy makers how climate change and extreme weather events may escalate the fiscal deficit and debt levels and the appropriate policy measures needed to address this issue.

This study also updates the climate literature and provides relevant insights to policy makers on the extent to which strengthened institutions and adaptive capacities can moderate climate change impacts on fiscal deficits. The second empirical paper sheds light on how monetary policy formulation may be affected by the external shocks caused by climate change on food price and general price levels through agricultural productivity. The study further contributes to the extant literature by providing empirical evidence of the role weather events play in widening income inequality. Furthermore, this thesis provides policy insight on the roles that both fiscal and monetary policies play in ensuring income redistribution in Africa. Particularly, it provides specific policy tools that are most effective in addressing widespread within-country income inequality among African households.

1.7 Scope and Limitations of the study

This study focuses on the effects that climate change and weather events have on fiscal balance, inflation and income inequality. It also addresses the role fiscal and monetary policies play in ensuring income redistribution in Africa. The study includes 52 African countries. The list of the countries used in the study is shown in the appendix. The study also covers the period 1990 – 2017 based on data availability especially for fiscal balance, monetary policy rate and tax.

1.8 Organisation of the study

This study is structured into six chapters. Chapter one is the general introduction and includes the background to the study, problem statement, research questions, objectives, scope and limitations of the study, significance of the study and ends with the organisation of the study. Chapter two presents the first empirical paper on the implications of climate change and extreme weather events for fiscal balance and fiscal policy in Africa. The second empirical paper is captured in chapter three and this discusses the implications of extreme weather events for inflation and monetary policy in Africa. Chapter four presents paper three on the persistence of income inequality in Africa: do weather events play any significant role? The fourth and last empirical paper on the distributional effects of fiscal and monetary policies in Africa is presented in chapter five. Chapter six presents the summary of the study, conclusion and policy recommendations.

CHAPTER TWO

THE IMPACTS OF CLIMATE CHANGE & EXTREME WEATHER EVENTS ON FISCAL BALANCE AND THE IMPLICATIONS FOR FISCAL POLICY IN AFRICA

Abstract

African countries quite often experience weather-related events as a result of climate variabilities. This study investigates 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. The paper employs the System Generalized Method of Moments, Fixed Effects and Random Effects estimation strategies over the period 1990 - 2017. The findings show that an increase in temperature change which implies a warmer climate in a meteorological year worsens fiscal balance in Africa. The 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 moderate the impacts of temperature change anomaly and extreme weather events on fiscal balance. The paper forecasts that the frequent incidence of climatic disruptions and extreme weather events which are considered external shocks, may harden the fiscal consolidation efforts and debt sustainability measures of some African governments[1].

Keywords: Climate change, Extreme weather events, Fiscal balance, Institutions, Africa.

JEL classification: H61, H68, Q51, Q54, Q58

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[1] Kunawotor, M. E., Bokpin, A. G. Asuming, O. P. & Amoateng, K. (2022). The Implications of Climate Change & Extreme Weather Events for Fiscal Balance and Fiscal Policy in Africa. *Journal of Social & Economic Development.* DOI: 10.1007/s40847-022-00180-6.

2.1 Introduction & 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 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 21st century (IPCC, 2012; IPCC, 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 21st century.

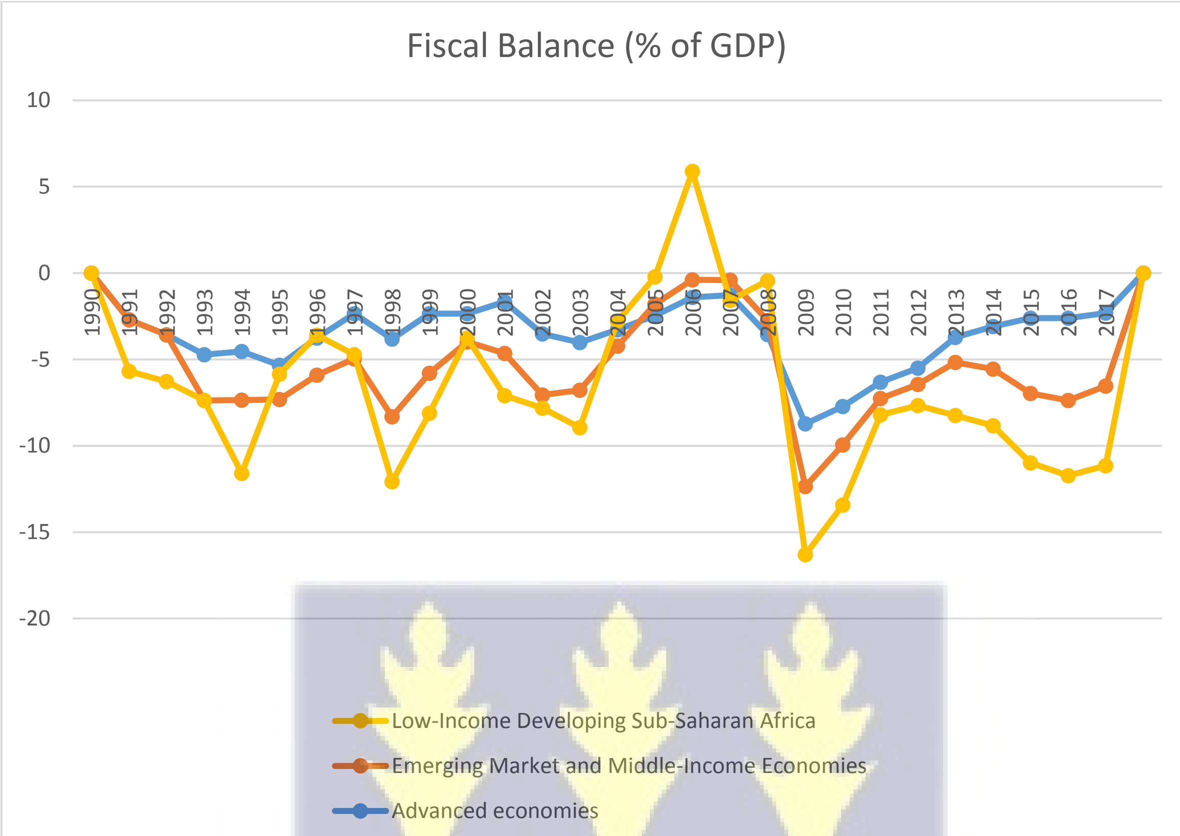
There is enough available scientific support (see Kireyev, 2018; Lis and Nickel, 2010; IPCC, 2007) to back the assertion that the rise in the severity and frequency of extreme weather events are due to climate change disruptions. Also, the Center for Research on the Epidemiology of Disasters (2017) asserts 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 include 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, increase in average temperature by 1°C can reduce GDP per capita by about 1.5 percent in sub-Sahara Africa. Other studies (see Cashin, Mohaddes, and Raissi, 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 in a number of countries. 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 Figure 2.1).

Figure 2.1: Regional distribution of Fiscal Balance for the period 1990 - 2017



Source: Authors construct from IMF data (2019)

Moreover, there are urgent and burgeoning issues with poverty and inequality that require critical attention within the limited fiscal space. It is even dire 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 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, this study investigates the effects of climate change and extreme weather events on fiscal balance in Africa and the implications for fiscal policy formulation. This 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, the study investigates the extent to which institutions and adaptive capacity moderate the impacts of extreme weather events and climate change on fiscal balance. The 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 recommendations.

2.2 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 reasons 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 macroeconomic 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.

2.2.1 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. In terms of the pathways of impact, higher temperatures have wide-ranging effects in poor nations, reducing agricultural output, industrial output, and aggregate investment, and increasing political instability. Also, Alagidede, Adu and Frimpong (2014) and Odusola and Abidoye (2012) established in their studies that, increases in temperature reduces economic performance in Sub-Saharan Africa and Africa respectively.

2.2.2 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. The study found real GDP growth, stock market price and past debt to be positively associated with budget balances. On the other hand, interest rate and elections are negatively associated with budget balances. Similarly, but centered on European countries, Bayar and Smeets (2009) modelled 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. While lagged debt, inflation and real GDP are positively related to fiscal balance, weather event, interest rate and election are negatively related. 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.

2.2.3 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.

2.2.4 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 is 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 towards adaptation than mitigation.

The closest to this present 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.

This study differs from that of Lis and Nickel's in so many ways. The paper focuses on the effects of climate change and extreme weather events on budget balance in Africa. It also concentrates on the roles institutions and adaptive capacity play in moderating the effects of extreme weather events and climate change on fiscal balance. 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 and 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.

2.2.5 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.

2.3. Methods

2.3.1. Model specification, Variable measurement and a priori expectations

The model used in this paper 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, elections) on change in budget balance. However, the specified models in this paper takes 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 the models take these forms;

Model 1: The Effects of Climate change &Weather Events on Fiscal balance

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

$$Fisbal_{it} = \sigma_1 Fisbal_{it-1} + \sigma_2 WeatherEvents_{it} + \beta' X_{it} + \varphi_i + \varphi_t + \gamma_{it} \ldots\ldots (1b)$$

Model 2: The Moderating effects of Institutions & Adaptive capacity on Fiscal balance

$$Fisbal_{it} = \omega_1 Fisbal_{it-1} + \omega_2 WeaEvents_{it} + \omega_3 Inst_{it} + \omega_4 (WeaEvents_{it} * Inst_{it}) + \beta' X_{it} + \eta_i + \eta_t + \tau_{it} \ldots$$

(2a)

$$Fisbal_{it} = \eta_1 Fisbal_{it-1} + \eta_2 WeaEvents_{it} + \eta_3 Adapcap_{it} + \eta_4 (WeaEvents_{it} * Adapcap_{it}) + \beta' X_{it} + \theta_i + \theta_t + \omega_{it}$$

.... (2b)

Model 3: The Moderating effects of Institutions on Fiscal balance - Climate Change

$$Fisbal_{it} = \pi_1 Fisbal_{it-1} + \pi_2 c\lim\Delta_{it} + \pi_3 Inst_{it} + \pi_4 (C\lim\Delta_{it} * Inst_{it}) + \beta' X_{it} + \psi_i + \psi_t + \lambda_{it} \quad \ldots\ldots (3)$$

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.

The main independent variables are climate change and weather events. Climate change ($clim\Delta_{it}$) 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 ($WeatherEvents_{it}$) 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. The first classification which is called "Weather Event 1" follows exactly the criterion which is used by EM-DAT under disaster sub-group climatological, hydrological or meteorological.

Secondly, the paper classifies 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 (1,000), 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, Keck and Teh (2010). The reason they give is that, for a weather events to have substantial effect on budget balance, it needs to be large enough.

A third weather event category is created and named "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 (1,000), 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. It is however expected that all weather events variables will 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, equation (2a, 2b & 3), the paper seeks to find how institutions ($Inst_{it}$) and adaptive capacity ($Adapcap_{it}$) 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, Kraay and Mastruzzi (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. It is expected that countries with relatively strong institutions will 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 - 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. The study expects 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 it is expected that inflation will have a 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 labour force modeled International Labour Organisation (ILO) estimate. It is expected that high unemployment rate will have a 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. This may lead to the crowding-out effect on both private and government entities competing for funds. 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. The paper expects a negative relation 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.

2.3.2 Data sources and Scope

This study deploys panel dataset and the sample period covers 1990 – 2017. The study includes 52 African countries shown in Appendix 1. The data on overall fiscal balance is 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 is 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, Hoeffler and Rohner (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).

2.3.3 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, Abor, Osei & Sa-Aadu, 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. Reverse causality may exist as climate change requires high adaptation and mitigation spending leading to high deficits. Also, high deficits and debt may need to be financed through alternative revenue generating mechanisms such as intensified deforestation and desertification which may trigger climate change. Fourth, the outcome variable is known to be persistent. Thus, current fiscal balance is influenced by its past values as suggested and used by Lis and Nickel (2010). 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, the Fixed-effects and Random-effects estimation techniques are deployed as robustness checks.

2.4. Findings

2.4.1 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 2.1. 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 as a whole.

The paper further tabulates 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 2.2 Out of a total of 1,456 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 2.3. This indicates the correlation between the variables used in the model and shows the basis for any multicollinearity. There are no concerns for multicollinearity.

Table 2. 1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Weather Event 1	1456	.931	1.229	0	9
Weather Event 2	1456	.296	.58	0	5
Weather Event 3	1456	.725	.994	0	8
Temperature change	1279	.70192	.4054	-.726	2.39
Fiscal balance	1270	-2.522	4.742	-18.073	20.482
Conflict	1407	.104	.306	0	1
Elections	1423	.182	.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	.285	37.94
Real interest rate	869	10.461	49.649	-93.513	1158.026
Debt ratio	1289	69.562	63.051	.278	485.668
Institutions	988	-.628	.588	-2.1	.88
Control of corruption	988	-.603	.6	-1.826	1.217
Gov’t Effectiveness	987	-.707	.599	-1.89	1.049
Political stability	988	-.506	.879	-2.845	1.282
Regulatory quality	988	-.667	.597	-2.298	1.127
Rule of law	988	-.662	.622	-2.13	1.077
Voice & Account’	988	-.622	.724	-2.226	1.007
Adaptation Index	1173	37.236	6.3578	25.238	55.918

Table 2. 2: Weather Events Tabulation from 1990 - 2017

Weather Event 1			**Weather Event 2**			**Weather Event 3**		
Variable count	Frequency	Percent	Count	Frequency	Percent	Count	Frequency	Percent
0	689	47.32	0	1,099	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	1,456	100	Total	1,456	100	Total	1,456	100

Source: Authors construct (2020) from EM-DAT data

Table 2.3: 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

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

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 warmer climate worsens the fiscal balance in Africa by specifically contributing to a higher fiscal deficit. The study finds 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 towards 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). 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.

The paper finds unemployment to have a positive and significant effect on fiscal balance even though it 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 neither be a frequent phenomenon nor non-existent 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. The study also finds no statistically significant effect of conflict and lag of real interest rate on fiscal balance in the sample of African countries. These results are robust to Fixed-effects and Random-effects estimations shown in Model 13 – Model 16 in Table 2.7.

Table 2. 3: The Effects of Temperature Change & 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 & Model 4 address the effects of weather event 1, weather event 2 & weather event 3 on fiscal balance.

2.4.3 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 4.1. The 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 2.5. 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 Table 2. 7.

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 2.6.

In addition, the paper interacts the various components of institutions with extreme weather event (weather event 2) and temperature change shown in Table 2.5 and Table 2.6 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 & -0.0391 in Model 6, Model 7 and Model 8 respectively in Table 2.5. 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 & -1.050 in Model 11 and Model 12 respectively in Table 2.6. 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 intuition of this finding is that, countries with stronger institutions have effective governance structures, less corruption, regulatory quality mechanisms and there is a strong voice and accountability system to ensure that disaster management organisations are well-resourced and operate effectively and independently to adjust to any adverse weather events impacts. They are well prepared and able to absolve a significant financial losses because monies have supposedly been put aside for such purposes. The converse 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 2.5. This means that, countries with weak systems and structures may have late warning systems which has severe consequences for fiscal balance and fiscal policy formulation through higher post-disaster relief expenditure and lower tax revenue from productivity losses.

Table 2. 4: The Moderating role of Institutional variables & Adaptive capacity – Weather Event 2

VARIABLES	MODEL 5	MODEL 6	MODEL 7	MODEL 8	MODEL 9
Lag of Fiscal balance	0.519***	0.521***	0.518***	0.502***	0.421***
	(0.109)	(0.103)	(0.098)	(0.106)	(0.084)
Weather Event 2	-0.832**	-0.843**	-0.756***	-0.579*	-0.272
	(0.361)	(0.364)	(0.265)	(0.286)	(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 & Accountability	--	--	--	-0.382	--
				(0.457)	
Event 2 - Voice & Acct'	--	--	--	-0.868*	--
				(0.440)	
Adaptation Index	--	--	--	--	-0.249
					(0.423)
Event 2 - Adapt' Index	--	--	--	--	-0.800*
					(0.466)
Conflict	0.382	0.451	0.595	0.355	0.038
	(0.618)	(0.539)	(0.543)	(0.518)	(0.358)
Elections	-0.638	-0.630	-0.685	-0.624	-0.545
	(0.518)	(0.511)	(0.514)	(0.505)	(0.328)
Inflation	-0.024	-0.019	-0.020	-0.024	-0.010
	(0.016)	(0.017)	(0.017)	(0.015)	(0.012)
GDP growth rate	0.180**	0.188***	0.184**	0.184***	0.196***
	(0.068)	(0.067)	(0.068)	(0.066)	(0.045)
Unemployment	0.093***	0.093***	0.079***	0.087***	0.085***
	(0.021)	(0.023)	(0.019)	(0.019)	(0.023)
Lag of real interest	0.017	0.013	0.016	0.014	0.011
	(0.017)	(0.016)	(0.017)	(0.017)	(0.011)
Lag of debt ratio	0.007***	0.007***	0.008***	0.008***	0.007***
	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)
Constant	-2.762***	-2.798***	-2.367***	-2.676***	-2.371***
	(0.614)	(0.605)	(0.648)	(0.577)	(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
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 & Institutions. Model 6, Model 7 & Model 8 contain the interaction of weather event 2 with government effectiveness, regulatory quality & voice and accountability respectively. Model 9 contains the interaction of weather event 2 with adaptive capacity.

Table 2.5: The Moderating role of Institutional variables on Fiscal balance - Temperature change

VARIABLES	MODEL 10	MODEL 11	MODEL 12
Lag of Fiscal balance	0.484***	0.479***	0.478***
	(0.100)	(0.092)	(0.109)
Temperature change	-2.173***	-1.934***	-2.222***
	(0.780)	(0.690)	(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	-0.008	-0.394
	(0.569)	(0.530)	(0.492)
Elections	-0.609	-0.608	-0.577
	(0.553)	(0.544)	(0.562)
Inflation	-0.028*	-0.028*	-0.027*
	(0.014)	(0.015)	(0.014)
GDP growth rate	0.153**	0.157**	0.153**
	(0.060)	(0.061)	(0.057)
Unemployment rate	0.079***	0.074**	0.084***

	(0.027)	(0.028)	(0.023)
Lag of interest	0.015	0.015	0.017
	(0.018)	(0.018)	(0.018)
Lag of debt ratio	0.007**	0.008***	0.007**
	(0.003)	(0.002)	(0.003)
Constant	-1.198	-1.163	-1.359
	(1.011)	(0.915)	(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.

Table 2.6: Robustness checks for Main results using Fixed-Effects (FE) & Random-Effects (RE)

VARIABLES	MODEL 13 RE	MODEL 14 FE	MODEL 15 RE	MODEL 16 FE	MODEL 17 FE
Weather Event 2			-0.443**	-0.384*	-1.133**
			(0.219)	(0.212)	(0.423)
Temperature change	-1.654***	-1.682***			
	(0.441)	(0.461)			
Institutions					0.430
					(1.832)
Event 2 - institutions					-1.222*
					(0.683)
Conflict	-0.406	-0.861	0.089	-0.133	-0.255
	(0.541)	(0.743)	(0.536)	(0.700)	(0.833)
Elections	-0.672*	-0.617*	-0.744**	-0.718**	-0.689
	(0.359)	(0.360)	(0.326)	(0.327)	(0.437)
Inflation	-0.059***	-0.069***	-0.049***	-0.058***	-0.063**
	(0.021)	(0.023)	(0.018)	(0.019)	(0.030)
GDP growth rate	0.227***	0.221***	0.229***	0.220***	0.224**
	(0.064)	(0.065)	(0.056)	(0.057)	(0.082)
Unemployment	0.096**	0.140*	0.098***	0.114	0.169*
	(0.039)	(0.076)	(0.036)	(0.077)	(0.094)

Lag of interest rate	0.003	0.002	-0.005	-0.009	-0.017
	(0.025)	(0.027)	(0.025)	(0.027)	(0.034)
Lag of debt ratio	0.011***	0.012***	0.012***	0.013***	0.015***
	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)
Constant	-1.985***	-2.450***	-3.387***	-3.528***	-3.824***
	(0.641)	(0.864)	(0.522)	(0.576)	(1.161)
Observations	492	492	567	567	448
R-squared	0.116	0.118	0.096	0.097	0.110
Number of countries	27	27	30	30	30
Prob > chi2/ Prob > F	0.000	0.000	0.000	0.000	0.000

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

2.5. Conclusion and Recommendations

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. The 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. The paper also find African countries with stronger institutions and adaptive capacities to endure less impacts of extreme weather events and temperature change anomalies.

The paper recommends that African countries should tighten their fiscal consolidation efforts as climate change and weather events may prove to be a destabilizer to these efforts. 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. It therefore suggests 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.

CHAPTER THREE

THE IMPACTS OF EXTREME WEATHER EVENTS ON INFLATION AND THE IMPLICATIONS FOR MONETARY POLICY IN AFRICA

Abstract

Climate change and weather-related events have long been resolved more by fiscal policy tools than that of monetary policy. However, recent discussions tend to point out that monetary policy could also be affected. This paper investigates the impacts of extreme weather events on headline inflation and food price inflation and their apparent implications for monetary policy formulation in Africa over the period 1990 - 2017. Using a two-step dynamic system Generalized Method of Moments with robust standard errors, the paper finds that weather-related events may need to occur on a large scale or be extreme to cause a significant price hike in Africa. Using Panel VECM, there is also sufficient evidence that there exists a bi-directional causality between inflation and extreme weather events in the long run. The paper also find the incidence of droughts and floods to have a bearing on food price inflation. Furthermore, the empirical evidence reveals that agricultural production serves as a perfect mediator through which extreme weather events affect headline inflation. As central banks are charged with the mandate of stable monetary environment, the paper suggests that monetary policy authorities consider the short and long run implications of supply shocks caused by extreme weather events on general price levels. Finally, anchoring inflation expectations should be a drive of policy makers as both headline inflation and food inflation appear quite persistent in Africa[2].

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[2] An extract from this chapter has been published; Kunawotor M. E., Bokpin, A. G., Asuming, O. P & Amoateng, K. (2021). The Impacts of Extreme Weather Events on Inflation and the Implications for Monetary Policy in Africa. *Progress in Development Studies,* 22 (2), 130 – 148.

3.1 Introduction & Motivation

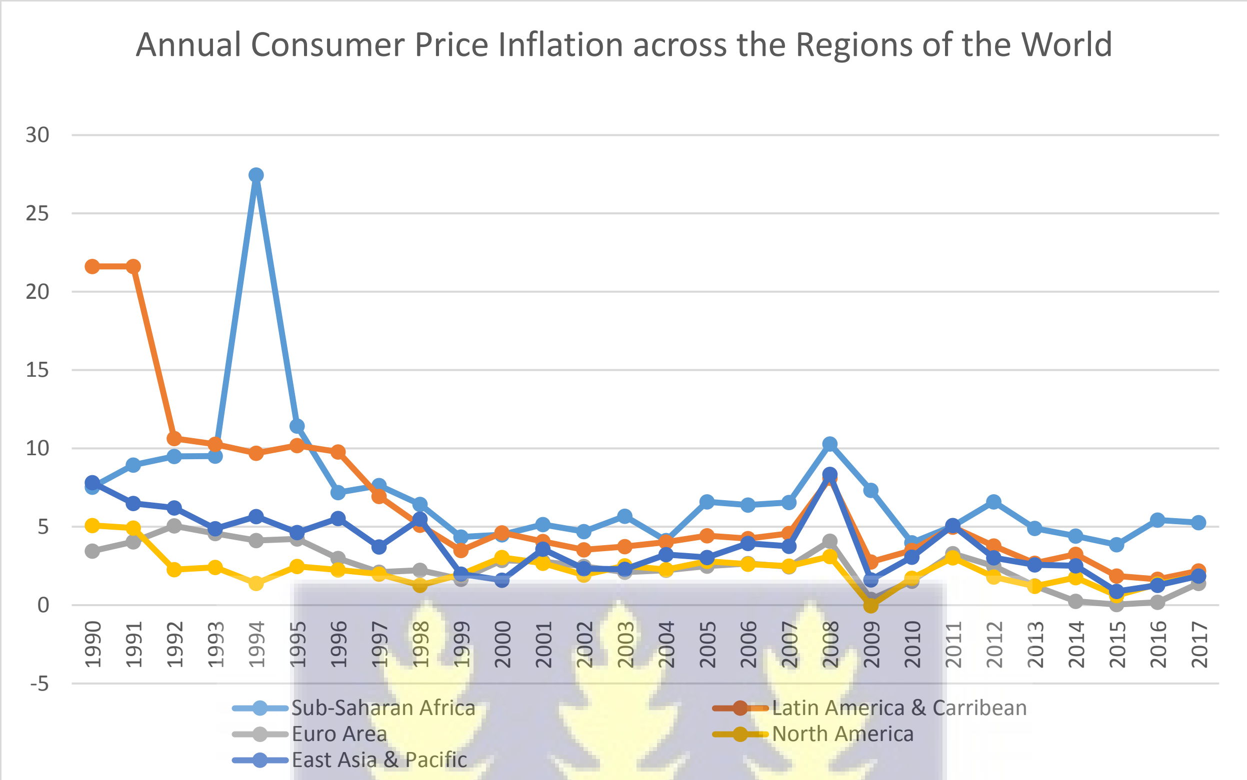
The world continues to experience climatic variabilities and these are noticeable through changes in the average weather pattern. The World Meteorological Organisation (WMO) defines climate change as long term changes in average weather conditions while the Food and Agricultural Organisation (FAO) defines it comprehensively as encompassing changes in long term averages for all the essential climate variables. Climate change is of global concern due to its linkage with the occurrence of several extreme weather events and natural disasters. Available evidence (see, Kireyev, 2018; Stott, 2016 and Stott et al., 2016) indicates that the severity and frequency of extreme weather events is due to climate change or global warming. These extreme weather events have had marked repercussions for global economic activities and have caused several damages to properties as well as injuries and deaths of persons. For example, estimate by the World Bank (2013) suggests that extreme weather events have caused about US$3 trillion worth of damages globally over the last three decades and this is projected to further cause more destructions due to climate change. A recent report by FAO (2017) also indicates that between the years 2008 to 2015, about 27 million people were displaced annually by natural hazards and climate related disasters and this trend keeps rising.

In Africa, about 51,569 people were killed and 412 million people were adversely affected due to 1,381 different forms of weather events over the period 1990 - 2019 as recorded in the emergency events database maintained by Center for Research on the Epidemiology of Disasters (CRED). Several studies have gone forth to gauge the economic implications and consequences of climate change and extreme weather events. While some of these climate change impact studies focus on the consequences of climate change and weather events for economic growth (Alagidede et al., 2014; Cavallo and Cavallo, 2014; Klomp and Valckx, 2014; Cavallo and Noy, 2011 and Dell et al., 2009, 2012), others focus on the implications for fiscal policy (Kunawotor et al., 2020; Lis and Nickel, 2010). Few others also focus on the implications for income inequality (Dasgupta et al., 2020; Kunawotor et al., 2020; Otrachshenko and Popova, 2019 and Diffenbaugh and Burke, 2019) and poverty (UNDESA, 2020; Brugnach, Craps and Dewulf, 2017).

The implications of climate change and extreme weather events for monetary policy have been largely neglected and this is confirmed by Economides & Xepapadeas (2018) and Olovsson (2018). This neglect they argue is because, climate change mitigation policies follow the classic economic approach of correcting externalities and hence, best solved through fiscal measures. Also, climate change issues are long term issues while monetary policy principally focuses on price and output stabilization which are short term measures, therefore there appears to be a mismatch and perhaps a weak relationship. However, studies using Neo-Keynesian models (Economides and Xepapadeas, 2018; Annicchiarico and Di Dio, 2017) show that monetary policy and central banks may have a role to play in the fight against climate change. Economides and Xepapadeas (2018) particularly argue that, although monetary policies are not directly climate policy instruments, the question to be answered is if monetary policy design could be affected by climate change.

Consequently, this study delves into the impacts of extreme weather events on inflation and impliedly, monetary policy formulation in Africa. Inflation is the focal outcome variable because monetary policy in most countries including Africa largely concentrates on price stability or inflation targeting. For example, in Ghana and South Africa, a public announcement of a specific inflation rate is made by the Central bank and Ministry of Finance. The set inflation rate is explicitly indicated in the annual budget and then afterwards, the monetary policy committee of the central bank uses the monetary policy rate as a major tool in driving towards this targeted inflation rate. Batten et al. (2020) and McKibbin et al. (2017) lend support to this assertion as they affirm that the primary monetary policy objective of most central banks globally is to maintain price stability with the other macroeconomic outcomes such as output stability being secondary or additional objective. It is important to gauge the impacts that extreme weather has for inflation and its implications for monetary policy because such an understanding according to Parker (2017) can provide a guide to monetary policy makers on how to set price levels in the aftermath of a disaster. Understanding the impacts of extreme weather events on inflation particularly in Africa is imperative because, although headline consumer price inflation has been on the decline in the region over the last decade probably due to an improvement in macroeconomic policies, the African continent still has the highest inflation rates relative to other regions of the world as observed in Figure 3.1.

Figure 3.1: Regional per annum distribution of CPI Inflation (%) in the world



Source: Authors construct (2020) from WDI database

In addition, Nguyen et al. (2017) argue that the pressures associated with inflation management remain one of the biggest challenges of monetary policy makers in Africa as headline inflation remains very volatile in the sub-region because of the high proportion of food in the consumer price index. Food prices are also very volatile due to unstable agricultural production. That notwithstanding, a significant proportion of Africans heavily depend on agriculture for livelihood.

Recent estimates by the International Labour Organisation (ILO) show that more than half (55 percent) of the total employment in Sub-Saharan Africa are found in the agricultural sector while UNDP (2014) estimates also show that, over 70 percent of the African population are employed in agriculture. Any temporary shock in the form of climate change or extreme weather events will jeopardize the welfare of many Africans as the agricultural sector is generally considered to be a climate sensitive sector besides the continent bearing the most brunt of climate change impacts (Farid et al., 2016; World Bank, 2014; Lanzafame, 2014 and Stern, 2006). A number of studies (FAO, 2017; Willenbockel, 2011; Nelson et al., 2010 and Hertel, Burke and Dobell 2010) have even projected an increase in the world price of main traded staple crops as well as price of agricultural products mainly as a result of climate change, low agricultural productivity and population growth. According to the Food and Agriculture Organisation, climate shocks were one of the leading causes of acute food crisis and malnutrition in 2017, affecting 59 million people in 24 countries in Africa alone. FAO (2017) also projects that climate change could add about 12% to food prices by 2030 in Africa, where food consumption of the poorest households amounts to over 60% of their total spending.

This study in addition to investigating the direct effect of extreme weather events on headline consumer price inflation, also investigates the direct effect on food price inflation. Furthermore, the paper investigates if agricultural productivity/production and its components could empirically serve as a conduit through which extreme weather events may impact inflation. This study differ from the few available climate change impact studies on inflation and monetary policy in many ways. While studies by Olovsson (2018) and Batten et al. (2020) are mere economic commentaries on the implications of climate change for financial stability and monetary policy, the study by Mckibbin et al. (2017) principally focused on designing an optimal monetary framework. Yet still, others focused on only floods and hurricanes in the Caribbean (see Heinen, Khadan and Strobl, 2018) or on natural disasters in general (Parker, 2017). None of these studies comprehensively focused on climate change induced-weather related events impacts on headline inflation or food inflation in Africa. None of these studies empirically showed the channels of impact through agricultural production.

3.2 Literature Review

3.2.1 Theoretical Review

There are two main schools of thought in macroeconomics literature on the theories of inflation and these are the structuralist and monetarist perspectives. The structuralist put more emphasis on supply side sources of inflation arising from cost of production in the form of high labour cost or rise in materials/input cost (Bernanke, 2005). On the supply side, an increase in the cost of production due to high wage demands or import duties leads to a reduction in aggregate supply and a rise in the general price levels. The monetarist view put emphasis on demand side factors such as expansionary fiscal and monetary policies (Friedman, 1963; Hendry, 2001). The demand side explains that an injection of more money into the system leads to high demand for goods and services and under the assumption of full employment of inputs, prices increase. Others (Mankiw, 2012) think inflation could be a consequence of both demand and supply side factors. This study captures both supply side and demand side sources in explaining inflation although the focus is on the supply side sources. Where inflation is predicted to be driven by supply deficiencies or supply shocks due to climate change and extreme weather events.

3.2.2 Empirical Review

The empirical review is sub-divided into four sections. These include a review of the effects of climate change and extreme weather events on agricultural yield and production; the effects of climate change, extreme weather events and disaster on inflation; climate change and monetary policy; and the empirical determinants of inflation. These are discussed below.

3.2.2.1 The effects of climate change and extreme weather events on agricultural output

A recent study by Acevedo et al. (2018) to find out if weather shocks influence agricultural production reveal that higher temperature leads to a reduction in agricultural value added and crops production in low income developing countries. The study asserts that, the influence of the weather on economic activity can happen through a number of channels, the most obvious one being agricultural output since temperature and precipitation changes are direct inputs in crop production. Similar studies by Zhang et al. (2018); Dell et al. (2012) and Hsiang, (2010) reveal that extremely hot temperatures contract agricultural and industrial output in poor and middle income countries. Schlenker and Lobell (2010) also find a negative effect of higher temperature on the yield of cultivated crops in developing countries in Sub-Saharan Africa and this ranges from -5 percent to -22 percent of the yield. Loayza et al. (2012) also find droughts and storms to negatively affect agricultural output while floods have positive impact.

Barrios, Ouattara and Strobl (2008) study the impact of climate change on the level of total agricultural production in Sub-Saharan Africa (SSA) and other non-Sub-Saharan African (NSSA) developing countries. The findings reveal that climate (changes in rainfall and temperature) is a major determinant of agricultural production in SSA while NSSA countries appear not to be affected in a similar fashion. Simulations using same estimates also show that the consequential changes in the climate since the early 1960s may be responsible for the differences in agricultural production between SSA and NSSA. FAO (2008) associates the following occurrences as the impacts caused by the increase in the frequency and severity of extreme weather events: damage to standing crops and stored crops; hike in waterborne livestock diseases; loss of livestock due to lack of feed and water stress; destruction of roads, bridges, storage structures, processing plants and electricity grids; lower yield in flooded agricultural areas and increase soil erosion can reduce future yields; pollution of water supply for crop irrigation; destruction of food supply chain and hence increase in distribution and marketing cost; increase in food prices; loss of farm income and food safety may be affected by water pollution.

A study by Maddison et al. (2007) on the impact of climate change on African agriculture finds that African agriculture is vulnerable to climate change. Particularly, regional climate change by 2050 is projected to cause a production loss of about 19.9 percent in Burkina Faso, 30.5 percent in Niger. Minimal losses are projected for South Africa of 1.3 percent and 3 percent for Ethiopia. Islam and Wong (2017) similarly assert that climate change causes destruction to crop production and distribution, affect the nutritional value of food and could also aggravate the risk of vector and waterborne diseases.

Climate change has detrimental impact on agricultural productivity in sub-Saharan Africa because the tropical climatic nature of the sub-region exposes post-harvest food products to pest infestations, micro-organisms and diseases (Firdaus et al., 2019). Also, droughts have grave impact on livestock and can cause deaths of these animals. Furthermore, Hendrix and Salehyan (2012) affirm that high precipitations due to climate change may cause damage to transportation networks especially in countries with poor roads systems and this will affect food distribution and infrastructure.

3.2.2.2: The impact of climate change, extreme weather events & disaster on inflation

Parker (2017) conducted a study on the impact of disaster on consumer price inflation among 212 economies. The study includes storms, earthquakes, floods and droughts as disaster types and find that there are marked heterogeneity in the impact caused by disaster on inflation between advanced and developing economies. The impact in advanced economies appears negligible while that of developing countries are disastrous and may last for three years after the disaster. The impact caused also differs depending on the inflation sub-indices and disaster type. Specifically, storms affect food price inflation while floods and droughts cause a rise in headline inflation. The paper by Heinen, Khadan and Strobl (2018) on the inflationary cost of extreme weather in developing countries differ from that of Parker (2017) in several ways. First, the concentration is on extreme weather events with a focus on hurricanes and floods. Secondly it is based on 15 Caribbean islands. Heinen et al. (2018) findings reveal that both hurricanes and floods cause a rise in general price levels as well as food prices. Floods appear to be more frequent than hurricanes but when a hurricane strikes, the resultant price effect is larger. The paper suggests that the potential short term inflationary cost caused by shortage of goods due to extreme weather events should not be ignored by policy makers.

Willenbockel (2012) focused on the impact of extreme weather events on food price fluctuations in 22 countries including 8 in Sub-Saharan Africa. The result suggests that extreme weather events in other crop-exporting countries does have significant impact on local food prices in Sub-Saharan Africa. Severe droughts and floods that may occur in the sub-region itself could have worst consequences. In terms of the channels of climate change and weather events impact on price levels, Olovsson (2018) mentions that the expected impact caused by climate change on inflation will not only emanate from the domestic agricultural sector but also, extreme weather can affect global food production and this may affect food price inflation especially among countries that import foodstuffs as the exporting countries reduce exports in order to curb domestic price levels. A typical example is when Russia stopped exporting cereals due to drought and heat waves in 2010. The impact of price hikes on cereals and headline inflation was experienced in many countries. Also, Firdaus et al. (2019) mention that extreme climate events could have effects on food product availability and this may cause price hikes affecting the income of the poor in low income countries.

3.2.2.3: Climate change, extreme weather events and monetary policy

A recent economic commentary by Olovsson (2018) on the relevance of climate change for central banks avers that the consequences of global warming may be relevant for central banks as they may plausibly have an impact on financial stability and monetary policy. The paper acknowledged that global warming cannot be appropriately counteracted by tools of monetary policy but rather more appropriately by fiscal policy. It however suggests that central banks should get involved by investing resources in understanding the possible effects of climate change on their economy's real sector and the implications for financial stability and monetary policy.

Mckibbin, Morris, Panton and Wilcoxen (2017) also narrate that extreme weather events as a result of climate disruptions may require the services of monetary policy makers in responding to any adverse supply shocks which could be transitory or permanent. Extreme weather events can cause damage to crops, flood major cities, industrial sites, cause extensive power outage, damage infrastructure and physical plants. This can affect output and prices and this may affect central bank's ability to forecast and manage inflation and other economic variables used for policy benchmarking. Similarly, study by Batten, Sowerbutts and Tanaka (2020) on the macroeconomic impact of climate change for monetary policy argue that, extreme weather events could have detrimental and significant impacts on the aggregate economy and inflation and this may require monetary authorities to react accordingly in response to the reactions of output and inflation. They argue weather-related events such as floods, droughts storms and sea level rise may cause inflationary pressures to arise due to a fall in national and international supply of agricultural commodities or productivity shocks. While the studies by Olovsson (2018) and Batten et al. (2020) represent more of economic commentaries, that of Mckibbin et al. (2017) though technical, principally focused on designing an optimal monetary framework in a carbon constrained and climatically-disrupted world.

3.2.2.4: Determinants of Inflation

The empirical literature on the drivers of inflation is very expansive but are mostly country specific studies with very few cross-country studies and the findings often inconclusive. For example, Adu and Marbuah (2011) empirically investigate the factors that account for inflation dynamics in Ghana and find nominal interest rate, broad money supply, real output, nominal exchange rate and fiscal deficit to be the dominant determinants. While real output and exchange rate have a negative relationship with inflation, a positive relationship exist between inflation on one hand and money supply, inflation expectations, nominal interest rate and fiscal deficit on the other. The study reveals output growth to have the strongest impact on inflation and accordingly suggests that, supply-side constraints should be the principal focus if inflation is to be moderated. Madito and Odhiambo (2018) study on the main empirical determinants of inflation in South Africa and found inflation expectations, labour cost, government expenditure and import prices to be positive drivers of inflation. The study however finds exchange rate and GDP as negative influencers. Durevall and Sjo (2012) captures the dynamics of inflation in Ethiopia and Kenya by including excess money supply, exchange rate, domestic agricultural supply shocks, world prices of food, non-food and energy prices in the model. Besides inflation inertia in both countries, their result show that exchange rate and world food prices have long run impacts while money growth and agricultural supply shocks have short to medium run effects on inflation.

A recent study by Nguyen, Dridi, Unsal and Williams (2017) on the drivers of inflation in Sub-Saharan Africa (SSA) find that domestic supply shocks, exchange rate shocks and shocks to monetary variables have been the key drivers of inflation in the past 25 years. This particularly include, oil and food imports, vulnerability to weather shocks, economic significance of agriculture and trade openness. They however find domestic demand shocks, global shocks and shocks to output to have accounted for the recent trend in inflation in SSA over the last decade. The country specific variables included in their model include, CPI, nominal effective exchange rate, broad money, nominal interest rate either deposit or discount rates, real GDP, global oil and food prices. Anderson, Masuch and Schiffbauer (2009) using a dynamic panel estimation find inflation differentials across the Euro area countries to be determined by inflation persistence, GDP per capita, fiscal position, wage growth and product market regulations.

3.2.3: **Summary of gaps in literature**

The extant empirical literature so far has focused on the implications climate change, weather shocks and natural disasters have on agricultural output and inflation. Other strands of literature have concentrated on the relevant roles that central banks can play in the fight against climate change and conclude that monetary policy authorities may need to respond to the adverse effects of supply shocks caused by climate change. The last strand discusses the drivers or determinants of inflation and include variables such as vulnerability to weather shocks. Most of these studies concentrate on natural disasters in general, such as earthquakes, hurricanes or specific types of weather events such as droughts or floods but not climate change induced-weather events in general. Most studies also fail to address the direct effects of weather-related events on price level in African countries. Also, there are limited empirical evidences on the channels through which weather events affect inflation. This study fills these gaps by examining the effects climate change-induced weather events have on both food and headline inflation. In addition, this study examines the channels of impact mainly through agricultural productivity.

3.3 Methodology

3.3.1 Model specification, Definition & Measurement of variables and a priori expectations

This paper's main specified models have inflation (headline inflation and food inflation) to be predicted by the lag of inflation, weather events and a set of control variables as shown below.

The Effects of Weather events and event types on Headline inflation

$$Inflation_{it} = \alpha_1 Inflation_{it-1} + \alpha_2 WeatherEvents_{it} + \beta' X_{it} + \mu_i + \mu_t + \varepsilon_{it} \quad \ldots\ldots. (1)$$

The Effects of Weather events and event types on Food inflation

$$FoodInflation_{it} = \varphi_1 FoodInflation_{it-1} + \phi_2 WeatherEvents_{it} + \beta' X_{it} + \eta_i + \eta_t + \xi_{it} \quad \ldots.. (2)$$

The mediating role of agricultural productivity/production on inflation

$$Inflation_{it} = \alpha_1 Inflation_{it-1} + \alpha_2 WeatherEvents_{it} + \beta' X_{it} + \mu_i + \mu_t + \varepsilon_{it} \quad \ldots\ldots (3a)$$

$$Agricproductivity_{it} = \sigma_1 Agricproductivity_{it-1} + \sigma_2 WeatherEvents_{it} + \beta' X_{it} + \gamma_i + \gamma_t + \varpi_{it} \quad \ldots (3b)$$

$$Inflation_{it} = \theta_1 Inflation_{it-1} + \theta_2 WeatherEvents_{it} + \theta_3 Agricproductivity_{it} + \beta' X_{it} + \phi_i + \phi_t + \pi_{it} \quad \ldots (3c)$$

Inflation ($inflation_{it}$) is the main outcome variable in all the models and it is defined as a sustained increase in the general level of prices of goods and services in a country. Inflation is measured by taking the logged difference of headline consumer price index (CPI). However, food inflation ($foodinflation_{it}$) which is a principal sub-component of headline inflation is introduced in equation (2). It is measured similarly by taking the natural log of food price inflation. The letters 'i' and 't' represent a given country and year respectively. Inflation is empirically found to show a considerable level of persistence which is also known as inflation inertia. Hence the introduction of the first lag of inflation ($inflation_{t-1}$). Inflation expectations (first lag of inflation) should therefore positively correlate with current level of inflation.

The main independent variable is weather event ($WeatherEvents_{it}$). Weather event is measured as a count variable based on certain set criteria and decision rule. An event is considered 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. The first classification which is called "Weather Event 1" follows exactly this criterion which is used by EM-DAT under disaster sub-group climatological, hydrological or meteorological.

Secondly, the paper classifies an occurrence as "Weather Event 2" (Large scale or extreme weather events) 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 (1,000), 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, Keck and Teh (2010).

A third weather event category is created and named "Weather Event 3" (Medium scale or extreme weather events) as a middle ground between large scale 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 (1,000), the estimated damage caused by the weather event is at least one million US dollars. It is worth noting that both “weather event 2” and “weather event 3” are referred in this study as “extreme weather events” due to the severity of their impacts. Generally, the paper expects the occurrence of weather event 1, weather event 2 and weather event 3 to cause an increase in food price inflation as well as headline consumer price inflation either directly or indirectly through a reduction in agricultural productivity/production.

The main types or sub-types of weather events in Africa over the sample period are flood, drought, storm, landslide, wildfire, extreme temperature, heat wave, cold wave, land fire, forest fire, tropical cyclone and mudslide. The paper therefore makes an attempt to find out which of these occurrence (s) is likely to directly or indirectly affect inflation. A particular attention is paid to floods and droughts as they happen to be the weather event types that are more frequent in Africa. Their effects on inflation are considered in equation (1) and (2). Floods and droughts are also measured as count variables just like “Weather Event 1” so long as they are considered and entered by EM-DAT. It is also expected that either floods or droughts may cause an increase in food inflation or headline inflation.

The study expects weather events to have both a direct or indirect effect on inflation. Indirectly, it is the expectation that weather events especially, extreme weather events will cause an agricultural productivity shock and hence an inflationary impact. The indirect effect is addressed using mediation analysis following the approach proposed by Baron & Kenny (1986). Three main conditions are required to be met in order to establish mediation according to Baron and Kenny (1986). These conditions are: First, the independent variable (Weather Events) must affect the dependent variable (inflation) as shown in equation (3a). Secondly, the independent variable (Weather Events) must affect the mediator (agricultural productivity/production) as shown in equation (3b). Thirdly, the mediator (agricultural productivity/production) must affect the dependent variable (inflation) in the presence of the independent variable (Weather Events) as shown in equation (3c). Partial mediation is said to occur when the effect of the independent variable (Weather Events) on the dependent variable (inflation) is less in equation (3c) than in (3a). Also, perfect or full mediation is said to occur when the independent variable (Weather Events) has no significant effect on the dependent variable (inflation) when the mediator (agricultural productivity) is controlled for.

Agricultural productivity ($Agricproductivity_{it}$) is measured using the net agricultural production value (2004-2006 constant value) computed by Food and Agricultural Organisation (FAO). Alternative measures used in this study are net agricultural production index also computed by Food and Agricultural Organisation (FAO) and an index computed using data of crop yield and livestock yield with the aid of principal component analysis. In addition, the paper uses the sub-components of agricultural production value such as crops net production value, food net production value and livestock net production value. It is expected that agricultural productivity or agricultural production will serve as a conduit through which weather events impact inflation. It is therefore expected that agricultural productivity/production will be negatively impacted by weather events. Thus, as weather event is introduced in the same model as agricultural productivity/production, the paper expects agricultural productivity/production to be significant with a negative sign while weather events either reduces in power (partial mediation) or become insignificant (full mediation).

A vector is introduced in all the models to represent the set of control variables (X_{it}) that affect inflation. The choice of these control variables are informed by theory or empirical literature.

These variables include real GDP, money supply, nominal interest rate, fiscal balance and exchange rate. Fiscal balance is measured as overall budget balance as a percentage of GDP. 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 paper expects increases in fiscal deficit to translate to higher inflationary rates due to excessive spending.

Real gross domestic product (GDP) is measured by real GDP. A negative relationship between real GDP and inflation is expected. This is because real GDP is used as a proxy for real income and an increase in real income is expected to lead to an increase in real money demand and hence cause a fall in inflation through a fall in the price of non-tradable goods. Nominal exchange rate is measured by the official exchange rate in the local currency unit to the United States dollars. It is expected that an increase in the nominal exchange rate (depreciation) will cause an increase in the general price level as prices of tradable goods also increase.

Nominal interest rate is proxied by deposit interest rate, lending interest rate and discount rate. However, deposit rate is mostly used due to data availability as the limited data on lending rate and discount rate reduces the sample size. Deposit rate is defined as the rate paid by commercial or similar banks for demand, time or savings deposits. An increase in interest rate is expected to cause an increase in consumer price inflation due to a resultant increase in the price of non-tradable goods. Money supply is measured by the taking the natural log of broad money. Broad money is defined as the sum of currency outside banks; demand deposits other than those of the central government; the time, savings, and foreign currency deposits of resident sectors other than the central government; bank and traveler’s cheques; and other securities such as certificates of deposit and commercial paper. It is expected that an increase in money supply will increase the general price level through an increase in the price of non-tradable goods. Finally, u_i, η_i & γ_i represent the country fixed effects, u_t, η_t & γ_t represent the time fixed effects. ε_{it}, ξ_{it}, ϖ_{it} & π_{it} are the idiosyncratic error terms.

3.3.2 Sources of data and Scope of the study

The study employs panel data over the period 1990 – 2017 and this includes 52 African countries (see Appendix 1). The data on inflation, deposit interest rate, nominal exchange rate, broad money supply and real GDP are sourced from the World Banks World Development Indicators (WDI). Data on fiscal balance is gleaned from the International Financial Statistics (IFS) of the International Monetary Fund (IMF) and African Development Bank (AFDB) Socio Economic database. Data on weather events and its types 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. This data is originally sourced from United Nations, non-governmental organisation and governmental agencies, research institutes, insurance companies and press agencies. The components of agricultural productivity, net agricultural production value, net agricultural production index and food price inflation are sourced from Food and Agricultural Organisation of the United Nations.

3.3.3. Estimation Technique

This paper employs the two-step system Generalized Method of Moments (GMM) estimation technique. In addition, the Panel Cointegration test and Vector Error Correction Model is deployed to find short and long run relationships. The choice of a dynamic two step GMM estimation approach with robust standard errors is motivated by five reasons in line with recent GMM-centric literature (Asongu et al., 2020; Asongu et al., 2019; Tchamyou et al., 2019; Agoba, Abor, Osei & Sa-Aadu, 2019; Fosu & Abass 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 a panel data and the empirical approach accounts for cross country differences in the estimation process.

Thirdly, our outcome variable, inflation is known to be persistent or dynamic and shows a great deal of inertia in Africa and hence depends on its lag (see Madito and Odhiambo, 2018; Durevall and Sjo, 2012; Adu and Marbuah, 2011 and Ocran, 2007). Fourth, when this dynamic nature of inflation is accounted for, it may results in possible endogeneity concerns. Accounting for the dynamic nature of inflation requires the introduction of its lag in the model which may result in possible endogeneity concerns. This endogeneity concern can be resolved by identifying an instrumental variable which is correlated with the endogenous independent variable but not the dependent variable. However, identifying a good instrument that has the above qualities and is supported by theory is usually difficult. In view of this, the GMM which generates its own internal instruments is employed to control for the possible endogeneity concerns in this study. Hence, simultaneity is tackled in this study by leveraging on lagged regressors which are employed as instruments.

Finally, GMM is preferred as it appears quite a tedious task finding external instruments and the system GMM estimator works for non-stationary data by employing additional moments conditions. 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)). All these diagnostic tests proved satisfactory in our study.

3.4. Empirical Results

3.4.1 Descriptive statistics, Frequency distribution and Correlation matrix

The summary statistics presented in Table 3.1 show the distributions of the variables used in our regression estimations. Consumer price inflation which is our main outcome variable has a mean of 8.52 percent which appears quite high in Africa relative to other continents. Regionally, West Africa has the lowest inflation rate (7.6 percent), followed by North Africa (8.12), East Africa (9.12 percent) and the highest being Southern Africa (12.6 percent). With regards to our main explanatory variables, 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.

This study further tabulates 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 3.2. Out of a total of 1,456 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. In the same vein, flood and drought have 58 percent and 21 percent probability of occurring in a year in Africa. There are generally no concern for multicollinearity in the models as shown by the matrix of correlations in Table 3.3. None of the correlations exceed 0.8.

Table 3. 1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Weather Event 1	1456	.931	1.229	0	9
Weather Event 2	1456	.296	.58	0	5
Weather Event 3	1456	.725	.994	0	8
Drought	1456	.205	.419	0	2
Flood	1456	.581	.913	0	7
Inflation	1233	8.52	11.288	-11.686	98.224
Fiscal Balance	1270	-2.522	4.742	-18.073	20.482
Interest rate	1037	9.079	8.932	1.107	147.125
Money supply	1382	34.056	27.33	2.857	251.618
Real GDP	1390	22.877	1.575	18.621	26.864
Agric productivity	1122	.026	1.778	-2.072	9.341
Agric NPV	1393	13.749	1.789	8.401	17.47963

Table 3. 2: Weather Events Tabulation from 1990 - 2017

Weather Event 1			**Weather Event 2**			**Weather Event 3**		
Variable count	Frequency	Percen t	Count	Frequenc y	Percen t	Count	Frequenc y	Percen t
0	689	47.32	0	1,099	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	1,456	100	Total	1,456	100	Total	1,456	100

Source: Authors construct (2020) from EM-DAT data

Table 3.3: Correlation Matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) Fiscal balance	1.000							
(2) Inflation	-0.086	1.000						
(3) Interest rate	-0.142	0.404	1.000					
(4) Exchange rate	0.097	-0.239	-0.162	1.000				
(5) Real GDP	0.050	0.030	0.007	-0.209	1.000			
(6) Money supply	-0.205	-0.140	-0.168	-0.352	0.215	1.000		
(7) Weather Events	0.017	0.081	0.084	0.086	0.299	-0.025	1.000	
(8) Agric productivity	-0.017	-0.021	-0.161	-0.162	0.584	0.529	0.092	1.000

3.4.2 Empirical results of the Direct Effects of Weather Events on Headline Inflation

The results of the direct effect of weather events on inflation reveal that weather event 1 has no statistically significant effect on headline inflation as shown in Model 1. However, weather event 2 and weather event 3 both have positive and statistically significant effects on headline consumer price inflation. This is shown in Model 2 & Model 3 in Table 3.4. Thus, the occurrence of weather event 2 causes a rise in headline inflation by 0.123 percentage points in Model 2. Similarly, the occurrence of weather event 3 causes a rise in headline inflation by 0.0750 percentage points in Model 3. This means that, weather events need to be large enough or severe (extreme weather events) to cause a significant upsurge in headline consumer price inflation in Africa.

Thus, the occurrence of extreme weather events (large scale and medium scale weather events) have dire implications for headline consumer price inflation as general price level may be affected probably due to the supply shocks they may create. Besides supply shocks, extreme weather events may flood major cities and industrial sites, cause extensive power outage, damage road infrastructure and physical plants, destroy storage structures, processing plants and electricity grids, destroy food supply chain and increase distribution and marketing cost. These trends may also be inflationary.

The findings also reveal that drought which is one of the types and sub-types of weather events has a positive and statistically significant effect on headline consumer price inflation as shown in Model 4. The occurrence of drought causes headline inflation to increase by 0.140 percentage points. This finding appears plausible as drought causes severe damage to farmlands and agricultural output and hence the possibility of causing a price hike. This paper however finds no statistically significant effect of flood on headline inflation in the sample shown in Model 5. The overall implication of these findings is that monetary policy authorities and central bankers in Africa may need to consider the impacts of extreme weather events in their inflation targeting mechanisms as they may tend to have an influence on general price levels. It is worth noting that even if the impact caused by extreme weather events on inflation is short-lived, it may have severe consequences on the welfare of poor households in the affected country as food expenditure happens to form a bulk of most household budgetary allocations.

Willenbockel (2012) lends support to this assertion and argues that, temporary food price hikes caused by extreme weather events may be unpredictable over a longer horizon and poor households and those in low income countries struggle to absorb or adjust to sudden shocks easily.

The study finds the first period lag of inflation to be statistically significant with a positive sign as expected throughout all the Models (Model 1 - 5). Thus, the immediate past headline inflation rate is an unbiased predictor of the current headline inflation rate. This is in line with the findings by Madito and Odhiambo (2018) and Adu and Marbuah (2012). Nominal interest rate is positive and statistically significant in all the models in conformity with theoretical predictions. This means that as interest rate rises, the cost of borrowing goes up and this increases the price of tradable goods and hence the general price levels. The study also finds a negative relationship between exchange rate and inflation and also between money supply and inflation. For the exchange rate, similar results were found by Adu and Marbuah (2012) for Ghana and Ndung'u (1997) for Kenya. Adu and Marbuah (2012) in particular explain that this may be due to exchange rate scarcity resulting in substantial transactions occurring at the parallel exchange rate. However the paper finds no statistically significant effect of fiscal balance and real income (real GDP) on inflation in the models. All the diagnostic test such as the F-statistics, Sargan test and Hansen test proved satisfactorily as shown in the various models and this confirms the reliability and accuracy of the results.

It is worth noting that using the Panel Cointegration and Panel Vector Error Correction Model, the results further show that there is a bi-directional causality between inflation and extreme weather events in the long run. But that is not the case in the short run as there is only a uni-directional causality in the short run from extreme weather events to inflation and not vice versa. These results are shown in Appendix 2.

Table 3. 3: The Direct Effects of Weather Events on Headline Inflation

VARIABLES	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
Lag of inflation	0.132*	0.133*	0.139*	0.128*	0.136*
	(0.074)	(0.073)	(0.073)	(0.074)	(0.073)
Weather Event 1	0.019				
	(0.029)				
Weather Event 2		0.123**			
		(0.057)			
Weather Event 3			0.075**		
			(0.035)		
Drought				0.140**	
				(0.067)	
Flood					0.036
					(0.040)
Interest rate	0.463***	0.459***	0.453***	0.467***	0.464***
	(0.085)	(0.086)	(0.085)	(0.086)	(0.085)
Fiscal balance	-0.011	-0.009	-0.011	-0.010	-0.011
	(0.008)	(0.007)	(0.008)	(0.008)	(0.008)
Exchange rate	-0.095***	-0.094***	-0.099***	-0.095***	-0.095***
	(0.034)	(0.034)	(0.033)	(0.034)	(0.034)
Real GDP	0.060	0.063	0.051	0.066*	0.057
	(0.041)	(0.039)	(0.041)	(0.039)	(0.041)
Money supply	-0.270*	-0.264*	-0.269**	-0.267*	-0.270*
	(0.135)	(0.136)	(0.133)	(0.135)	(0.134)
Constant	0.436	0.335	0.629	0.286	0.500
	(1.067)	(1.014)	(1.065)	(1.016)	(1.060)
Observations	674	674	674	674	674
Number of countries	40	40	40	40	40
Number of Instruments	10	10	10	10	10
Wald test (Prob > F)	0.000	0.000	0.000	0.000	0.000
AR(1):(Pr > z)	-3.95(0.000)	-3.92(0.000)	-3.99(0.000)	-3.93(0.000)	-3.97(0.000)
AR(2):(Pr > z)	0.99(0.321)	0.82(0.411)	1.02(0.306)	1.04(0.298)	1.01(0.314)
Sargan test	1.90(0.386)	2.05(0.359)	1.78(0.411)	1.84 (0.399)	1.86(0.394)
Hansen test	2.38(0.305)	2.67(0.264)	2.24(0.326)	2.24(0.326)	2.32(0.314)

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0: Model 1 addresses the effect of Weather Event 1 on headline inflation. Model 2 & Model 3 address the effects of Weather Event 2 and Weather Event 3 on headline inflation respectively. Model 4 & Model 5 addresses the effects of drought and flood on headline inflation respectively.

3.4.3 Empirical results of the Direct Effects of Weather Events on Food Price Inflation

Food price hike is known to be a major contributory factor to headline inflation in Africa. This said, Table 3.5 addresses the direct effects of weather events and event types on food price inflation. The paper finds no statistically significant effect of Weather Event 1, Weather Event 2 & Weather Event 3 on food price inflation as shown in Model 6, Model 7 & Model 8.

However, the findings of the weather event types and sub-types reveal that, drought has a positive and statistically significant effect on food price inflation as shown in Model 9. Flood also has a positive and statistically significant effect on food price inflation as shown in Model 10. Thus, the occurrence of drought causes a rise in food price inflation by about 0.253 percentage points while the occurrence of flood causes a 0.103 percentage point rise in food price inflation. These imply that the frequent incidence of either drought or flood may cause a hike in food prices and this may translate to a rise in the general consumer price inflation. This conforms to the findings by Willenbockel (2012) and the forecasts by FAO (2017) where food prices are projected to rise by 12 percent by 2030 as a result of climate change. Also, food price inflation is persistent as the lag of food price inflation is statistically significant in all the models (Model 6 – Model 10). Thus, past food inflation rate is an unbiased predictor of current food inflation rate.

Table 3. 4: The Direct Effects of Weather Events on Food Inflation

VARIABLES	MODEL 6	MODEL 7	MODEL 8	MODEL 9	MODEL 10
Lag of food inflation	0.338***	0.331***	0.350***	0.323***	0.352***
	(0.097)	(0.097)	(0.092)	(0.099)	(0.097)
Weather Event 1	0.059				
	(0.043)				
Weather Event 2		0.087			
		(0.183)			
Weather Event 3			0.103		
			(0.068)		
Drought				0.253*	
				(0.147)	
Flood					0.103**
					(0.043)
Interest rate	0.340**	0.353**	0.317**	0.358***	0.346**
	(0.139)	(0.133)	(0.141)	(0.124)	(0.132)
Fiscal balance	0.003	0.007	0.003	0.007	0.002
	(0.012)	(0.013)	(0.011)	(0.012)	(0.012)
Exchange rate	-0.062	-0.063	-0.062	-0.059	-0.064
	(0.047)	(0.048)	(0.046)	(0.047)	(0.047)
Real GDP	0.035	0.049	0.031	0.051	0.031
	(0.044)	(0.041)	(0.044)	(0.042)	(0.045)
Money supply	-0.472*	-0.458*	-0.466*	-0.449*	-0.458*
	(0.249)	(0.258)	(0.247)	(0.245)	(0.249)
Constant	1.605	1.291	1.673	1.178	1.614
	(1.455)	(1.408)	(1.399)	(1.376)	(1.517)
Observations	242	242	242	242	242
Number of countries	37	37	37	37	37
Number of instruments	9	9	9	9	9
Wald test (Prob > F)	0.000	0.000	0.000	0.000	0.000
AR(1):(Pr > z)	-2.33(0.020)	-2.33(0.020)	-2.41(0.016)	-2.39(0.017)	-2.32(0.020)
AR(2):(Pr > z)	-0.46(0.647)	-0.50(0.614)	-0.37(0.713)	-0.38(0.703)	-0.42(0.673)
Sargan test	0.69(0.406)	0.44(0.507)	0.50(0.482)	0.38(0.536)	0.93(0.336)
Hansen test	0.69(0.406)	0.48(0.490)	0.53(0.465)	0.42(0.518)	0.91(0.341)

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 Model 6, Model 7 & Model 8 address the effects of Weather Event 1, Weather Event 2 & Weather Event 3 on food inflation respectively. Model 9 & Model 10 address the effects of drought and flood on food inflation respectively.

3.4.4 Empirical results of the Indirect Effects of Weather Events on Headline Inflation through Agricultural Productivity/Production

Weather events may have either a direct or indirect effect on headline inflation. The indirect effect of weather event on inflation may be mediated by agricultural productivity. Thus, agricultural productivity/production may experience a setback upon happening of weather events and this may lead to an agricultural supply shock which may have an impact on food prices or the general price level. The result of the mediation analysis is presented in Table 3.6 and Table 3.7. Weather Event 2 has a positive and statistically significant effect (0.123) on headline inflation as shown in Model 11 when introduced alone. Weather Event 2 also has a statistically significant effect on agricultural production (0.0391) as shown in Model 12. Furthermore and more importantly, when agricultural production is controlled for, by being introduced in the same model (Model 13) with Weather Event 2, Weather Event 2 loses its statistical significance (0.127) while agricultural production becomes statistically significant with a negative sign (-0.430) as expected.

This result means that agricultural production reduces when Weather Event 2 occurs (extreme weather events) and this result to a rise in general prices. Thus, agricultural production serves as a conduit for Weather Event 2 to impact headline inflation. With regards to the components of agricultural production, the findings also reveal that crops production (-0.348), food production (-0.444) and livestock production (-0.277) reduce at the incidence of Weather Event 2 as shown in Model 14, Model 15 & Model 16 respectively. Thus, extreme weather events cause a negative shock to crops production, food production and livestock production and these lead to a rise in the general price level.

The result for the indirect effects of Weather Event 3 on headline inflation through agricultural production are similar to that of Weather Event 2 and it is presented in Table 3.7. Weather Event 3 also has a direct and statistically significant effect (0.0750) on consumer price inflation in Model 17. It also has a statistically significant effect (0.0365) on agricultural production in Model 18. It however loses its statistical significance (0.239) in Model 19 when agricultural production (-0.437) is controlled for. This implies that agricultural production serves as a full mediator for Weather Event 3 to affect inflation. Also, crops production (-0.350), food production (-0.449) and livestock production (-0.283) also serve as conduits for Weather Event 3 to affect inflation as shown in Model 20, Model 21 & Model 22 respectively.

The implication of these findings is that, the occurrence of extreme weather events (Weather Event 2 & Weather Event 3) cause a reduction in agricultural production and this tend to affect headline consumer price inflation. Generally, agricultural production is affected through damage to standing crops and stored crops; hike in waterborne livestock diseases; loss of livestock due to lack of feed and water stress; lower yield in flooded agricultural areas and increase soil erosion which reduces future yields; pollution of water supply for crop irrigation; destruction of food supply chain and hence increase in distribution and marketing cost and all these may lead to increase in food prices and general prices.

Table 3. 5: The Indirect Effects of Weather Event 2 on Headline Inflation through Agriculture

VARIABLES	MODEL 11	MODEL 12	MODEL 13	MODEL 14	MODEL 15	MODEL 16
Lag of inflation	0.133*		0.511**	0.459*	0.466*	0.451*
	(0.073)		(0.243)	(0.237)	(0.240)	(0.246)
Weather Event 2	0.123**	0.039**	0.127	0.082	0.120	0.116
	(0.057)	(0.018)	(0.081)	(0.084)	(0.082)	(0.075)
Lag of Agric product’		0.848***				

		(0.069)				
Agric production			-0.430**			
			(0.170)			
Crops production				-0.348**		
				(0.148)		
Food production					-0.444**	
					(0.182)	
Livestock production						-0.277**
						(0.133)
Interest rate	0.459***	0.086**	0.444**	0.419**	0.465**	0.391**
	(0.086)	(0.033)	(0.190)	(0.205)	(0.203)	(0.187)
Fiscal balance	-0.009	-0.003	-0.009	-0.012	-0.011	-0.004
	(0.008)	(0.002)	(0.009)	(0.009)	(0.009)	(0.008)
Exchange rate	-0.094***	0.023	0.001	0.011	0.001	-0.042
	(0.034)	(0.014)	(0.048)	(0.053)	(0.048)	(0.039)
Real GDP	0.063	0.093	0.642***	0.573**	0.660**	0.496**
	(0.039)	(0.080)	(0.228)	(0.217)	(0.245)	(0.186)
Money supply	-0.264*	0.019	-0.380**	-0.478**	-0.415**	-0.224
	(0.136)	(0.107)	(0.182)	(0.199)	(0.188)	(0.160)
Constant	0.335	-0.333	-7.739**	-6.992**	-7.798**	-6.974**
	(1.014)	(0.994)	(3.133)	(3.080)	(3.335)	(2.798)
Observations	674	836	648	638	638	638
Number of countries	40	41	40	39	39	39
Number of instruments	10	9	17	17	17	17
Wald test	0.000	0.000	0.000	0.000	0.000	0.000
AR(1):(Pr > z)	(0.000	(0.000	(0.005)	(0.005)	(0.006)	(0.005)
AR(2):(Pr > z)	(0.411)	(0.043)	(0.193)	(0.203)	(0.214	(0.238)
Sargan test	(0.359	(0.049	(0.456)	(0.266)	(0.234	(0.273)
Hansen test	(0.264)	(0.143)	(0.484)	(0.544)	(0.463)	(0.604)

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 Model 11 shows the effect of Weather Event 2 on headline inflation. Model 12 shows the effect of Weather Event 2 on agriculture production. Model 13 addresses the mediating effect of agriculture production when introduced with Weather Event 2. Model 14, 15 & 16 address the mediating effect of crops production, food production & livestock production respectively when introduced with Weather Event 2 albeit independently.

Table 3. 6: The Indirect Effects of Weather Event 3 on Headline Inflation through Agriculture

VARIABLES	MODEL 17	MODEL 18	MODEL 19	MODEL 20	MODEL 21	MODEL 22
Lag of inflation	0.139*		0.499**	0.450*	0.454*	0.450*
	(0.073)		(0.239)	(0.234)	(0.234)	(0.238)
Weather Event 3	0.075**	0.037**	0.059	0.028	0.046	0.033
	(0.035)	(0.015)	(0.046)	(0.047)	(0.046)	(0.047)
Lag of Agric product'		0.871***				
		(0.069)				
Agric production			-0.437**			
			(0.181)			
Crops production				-0.350**		
				(0.153)		
Food production					-0.449**	
					(0.192)	
Livestock production						-0.283*
						(0.140)
Interest rate	0.453***	0.078**	0.448**	0.421**	0.468**	0.385**
	(0.085)	(0.034)	(0.183)	(0.200)	(0.196)	(0.181)
Fiscal balance	-0.011	-0.003	-0.012	-0.014*	-0.014	-0.006
	(0.007)	(0.003)	(0.008)	(0.008)	(0.009)	(0.008)
Exchange rate	-0.099***	0.017	-0.007	0.006	-0.006	-0.045
	(0.034)	(0.012)	(0.050)	(0.056)	(0.051)	(0.039)
Real GDP	0.051	0.063	0.644**	0.574**	0.663**	0.497**
	(0.041)	(0.083)	(0.248)	(0.230)	(0.263)	(0.199)
Money supply	-0.269**	0.028	-0.402**	-0.494**	-0.439**	-0.247
	(0.133)	(0.111)	(0.179)	(0.197)	(0.188)	(0.161)
Constant	0.629	0.038	-7.590**	-6.894**	-7.675**	-6.793**
	(1.065)	(1.061)	(3.431)	(3.310)	(3.590)	(3.002)
Observations	674	836	648	638	638	638
Number of countries	40	41	40	39	39	39
Number of instruments	10	9	17	17	17	17
Wald test:	0.000	0.000	0.000	0.000	0.000	0.000
AR(1): (Pr > z)	(0.000)	(0.000)	(0.004)	(0.005)	(0.005)	(0.004)
AR(2): (Pr > z)	(0.306)	(0.042)	(0.166)	(0.184)	(0.183)	(0.200)
Sargan test	(0.411)	(0.008)	(0.470)	(0.282)	(0.256)	(0.292)
Hansen test	(0.326)	(0.057)	(0.559)	(0.570)	(0.519)	(0.642)

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 Model 17 shows the effect of Weather Event 3 on headline inflation. Model 18 shows the effect of Weather Event 3 on agriculture production. Model 19 addresses the mediating effect of agriculture production when introduced with Weather Event 3. Model 20, 21 & 22 address the mediating effect of crops production, food production & livestock production respectively when introduced with Weather Event 3 albeit independently.

3.5. Conclusion and Recommendations

The empirical literature on climate change impact studies continues to attract a lot of interesting discussions. Typically, climate change mitigating policies are generally considered fiscal issues hence best addressed by fiscal policy instruments. However, recent discussions using Neo-Keynesian models argue that monetary policy and central banks may also be affected in some way. This study comprehensively investigates the direct effects of extreme weather events and the event sub-types on headline consumer price inflation and food price inflation and the implications for monetary policy in Africa. In addition, the paper examines the indirect effect of extreme weather events on headline inflation through agricultural production.

The findings reveal that the occurrence of weather-related events may need to be on a large scale or be extreme to cause a significant price hike in Africa. In addition, the paper finds droughts to have an impact on both headline inflation and food price inflation. Similarly, floods have the tendency to cause a rise in food price inflation. Also, the findings show that agricultural production serves as a full mediator through which extreme weather events impact consumer price inflation.

Taking cognisance of the fact that price and output stability are the primary duties of central banks and being fully aware that even short run impacts of extreme weather events could trigger long term implications for macroeconomic policy in general and also have dire implications for poor households in Africa, the paper suggests that monetary policy authorities consider the implications of supply shocks caused by extreme weather events on food price and the general price level in their inflation targeting mechanisms. Particularly, the inflation targeting models should be adjusted to take into consideration climate change-induced risk (extreme weather events) on food price inflation and headline inflation. This is because climate disruptions may make forecasting of output gap and inflation problematic. Also, anchoring inflation expectations should be a major drive of policy makers as both headline inflation and food inflation appear persistent in Africa. Additionally, the paper suggests that a buffer of food stuffs be kept on regular basis to serve as respite in times of eventualities in order to anchor inflation. It is worth mentioning that this study does not in any way suggest that the solution to climate change should come from monetary policy but rather, monetary policy authorities should consider climate change in their decisions.

CHAPTER FOUR

DO WEATHER EVENTS AFFECT INCOME INEQUALITY IN AFRICA?

Abstract

African countries continue to experience the cascading effects of climate change in the form of weather events even though highly industrialized nations are mostly responsible for these climatic variabilities. This paper investigates the impacts of weather events on income inequality in Africa over the period 1990 – 2017. The novel findings using the difference Generalized Method of Moments (GMM) estimation technique reveal a non-monotonic U-shape effect of the incidence of weather events on income inequality. The result of the simultaneous quantile regression shows that weather events increase income inequality at the 10th, 25th, 50th and 75th percent quantiles. In terms of weather events type, the paper also finds a non-monotonic U-shape effect of the incidence of flood on income inequality. Furthermore, institutions tend to moderate the impacts weather events has on income inequality. The paper however finds no statistically significant mediating effect of weather events on income inequality through agricultural productivity in the sample. Again, there is no significant moderating effect of adaptive capacity on income inequality. The paper suggests that income inequality concerns should not be ignored in global climate change discussions. Furthermore, African countries should strengthen their institutions and adaptive capacities as they remain very weak in the continent[3].

Keywords: Weather Events, Flood, Income Inequality, Institutions, Africa.

JEL classification: Q54, Q51, D31, D63, E02, O55.

[3] An extract from this chapter has been published; Kunawotor M. E., Bokpin, A. G., Asuming, O. P & Amoateng, K. (2021). Do Weather Events affect Income Inequality in Africa? *Interdisciplinary Environmental Review* 21(3), 148 – 176.

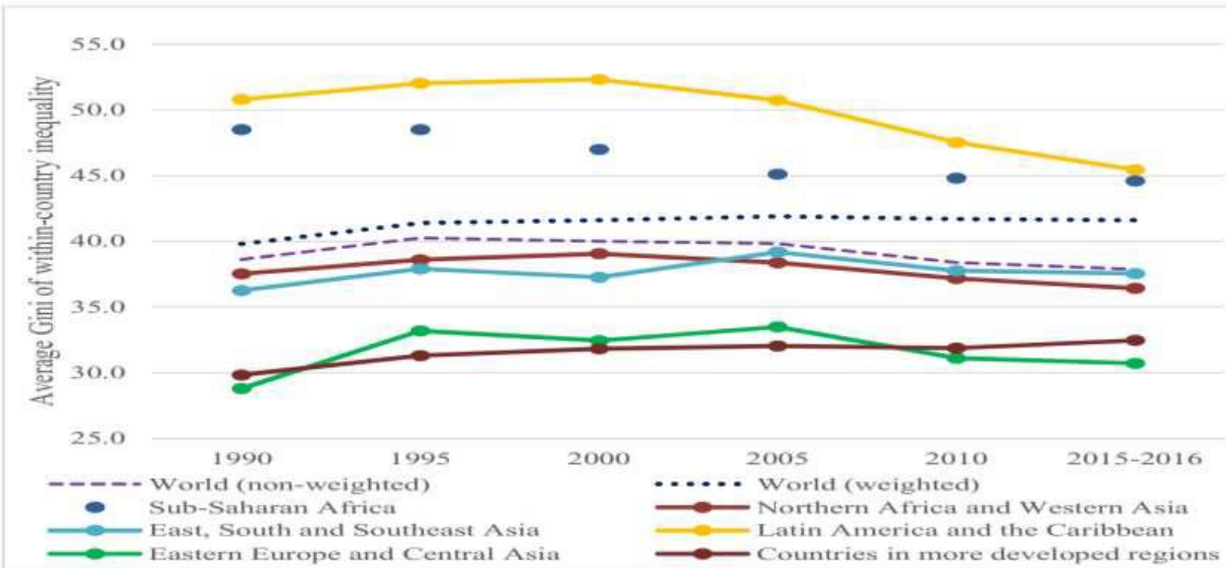
4.1 Introduction & Motivation

Climate change continues to be a pivotal focus of discussion amongst many world leaders and governments worldwide as it is considered a major threat (World Economic Forum, 2019) in this century. The importance of climate change is reflected in the United Nations Millennium Development Goals (MDGs) of ensuring environmental sustainability and now more visibly in goal 13 of the Sustainable Development Goals (SDGs) which discusses actions to reduce climate change impacts. Besides governmental efforts, the academic literature continues to churn lots of empirical evidence to buttress the dangers of climate change impacts for both the current and future generations. One key global evidence of climate change is the change in average temperature patterns and the frequent occurrence of extreme weather events in the form of floods, droughts, earthquakes, hurricanes, tremors, tornadoes, wildfires, etc. Available scientific evidence (see Kireyev, 2018; CRED 2017; Lis and Nickel, 2010) supports the assertion that the severity and frequency of extreme weather events are due to climate variabilities.

Weather events as captured by the Emergency Events Database (EM-DAT) are a special type of natural disasters that are climatological, meteorological or hydrological and may require the happenings of at least one of the following; 10 or more people killed, 100 or more people affected or injured, a declaration of a state of emergency by the affected country and/or a call for international assistance. 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. FAO (2017) also reports that between the years 2008 to 2015, about 27 million people have been displaced annually by natural hazards and climate-related disasters and this trend keeps rising. In Africa, about 51,569 people were killed and 412 million people adversely affected due to 1,381 different forms of weather events over the period 1990 - 2019 as recorded in the emergency events database maintained by the Center for Research on the Epidemiology of Disasters (CRED). Weather events have destroyed properties, thrown a lot of people in poverty and continue to widen the income disparities between the rich and the poor. Climate change and various forms of weather events also have detrimental impacts on economic growth (IMF, 2017; Cashin et al., 2017; Hallegatte et al., 2016) and agricultural productivity (Calvin et al., 2020; FAO, 2018; Mendelsohn & Massetti, 2017; Auffhammer & Schlenker, 2014; Dell et al., 2012). Particularly, FAO (2017) estimates suggests that 25 percent of the hazards caused by natural disasters affect agriculture and 80 percent of the damages caused by droughts affect the agricultural sector.

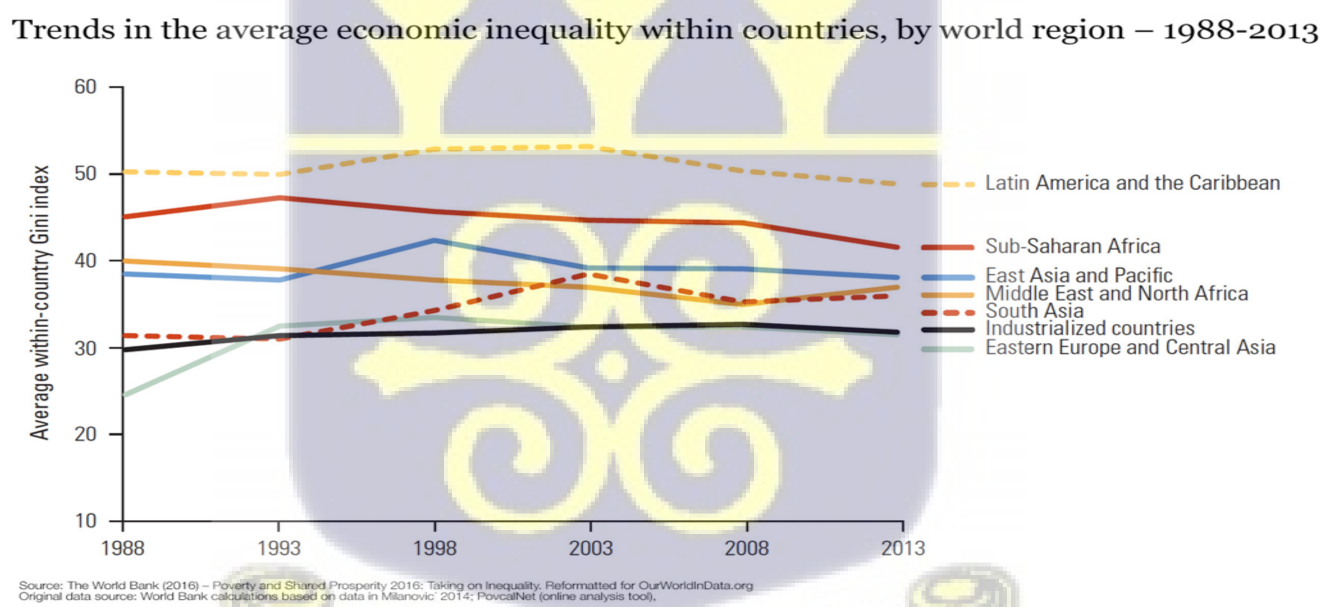
However, although the consequences of climate change are grave, inequality also seems to be a key concern on the global landscape and hence considered as one of the SDGs. Income inequality and climate change are a defining challenge of our time as the two are considered to be the two most important challenges currently facing the international community (UNDESA, 2016). These two reinforcing phenomena also simultaneously appear on the SDGs agenda and addressing them according to Markkanen and Anger-Kraavi (2019) is imperative to achieving most of the other SDGs. Not only do most African countries endure and continue to be the most affected by climate change impacts, but also, income inequality appears very high and persistent in Africa. The African continent ranks almost least in the regional distributions of income inequality performing just a little better than Latin America and the Caribbean as shown in Figure 4.1 & 4.2.

Figure 4.1: Regional Inequality trends from 1990 - 2016



Source: UNDESA (2019) from UNU-WIDER database

Figure 4.2: Regional inequality trends from 1988 - 2013



Source: World Bank (2016)

This assertion is alluded to by Shimeles and Nabassaga (2018); Odusola (2017); Anyanwu (2016). African countries also have had high levels of initial income inequality with ten out of the world's nineteen most unequal countries found in Africa (UNDP, 2017). High levels of economic inequality have numerous implications for economic growth, macroeconomic stability, poverty reduction and human sustainability (OECD, 2015; Cojocaru & Diagne, 2014; Ostry, Berg, & Tsangarides, 2014; IMF, 2014). UNDESA (2020) for instance argues that high inequality does not only harm the poor and disadvantaged groups but also affects the general well-being of society at large and also, highly unequal societies grow more slowly and find it very difficult in reducing poverty. Similarly, the available evidence (see Shimeles and Nabassaga, 2018; Fosu, 2015) show that no amount of growth in GDP per capita income amongst some African countries would be sufficient enough to reduce extreme poverty unless income inequality declines considerably.

However, recent studies albeit very few show that concerns of reducing economic inequality could further be hindered by changing climate and its adverse cascading effects in the form of weather events. For example, studies by UNDESA (2020); Dasgupta et al. (2020); Otrachshenko and Popova (2019); Diffenbaugh and Burke (2019) show that climate change and weather events worsen inequality. Attention is also being directed towards the risk climate change poses to exacerbating income inequality and achieving the Sustainable Development Goals (see Winsemius et al., 2018; Hallegatte & Rozenberg, 2017). Few others looked at the consequences climate mitigation policies have on inequality (Klinsky & Winkler, 2018; Brugnach et al., 2017). Yet still, UNDESA (2016) shows that climate change and income inequality are locked in a vicious cycle.

While most of these studies focus on temperature change or extreme weather (heat waves or cold waves) as proxies for climate change and mainly between-country income inequality except for Dasgupta et al. (2020) who focused on South Africa, no study was identified to comprehensively study the impact of weather events and its types on within-country income inequality in Africa.

Accordingly, this study attempts to investigate the effects of weather events and the various types, on income inequality in Africa. Also, it investigates the impacts that institutions and adaptive capacity play in moderating the impact of weather events on income inequality. Furthermore, it investigate if agricultural productivity mediates the impacts that weather events has on income inequality in Africa as climate-sensitive agriculture is noted to be the predominant form of livelihood for most Africans. The remaining sections of this study contains a literature review, data and methods, results and conclusions as well as some recommendations.

4.2. Literature Review

4.2.1 Climate change, Weather events & Poverty

Ludwig et al. (2007) narrate why the poor tend to be more affected by climate change impacts. First, many poor people live in semi-arid regions in Africa and Asia that are more likely to be affected by climate change impacts because these regions have an erratic climate with unpredictable rainfall patterns causing floods and droughts. Therefore, increased climate variability further pushes these people into poverty due to the loss of income and properties. Even, those in the urban centers settle in slums which are mostly flood-prone, and official developments not permitted. Secondly, the poor predominantly depend on vulnerable economic sectors such as agriculture which is susceptible to changes in rainfall and temperature in these regions. Since future rainfall patterns are unpredictable, their livelihood on agriculture is unsustainable. The amount of water available for irrigation is reduced especially for small-scale farmers.

The health concern of the poor is also jeopardized as they mostly have a low resistance to diseases caused by climate variabilities such as malaria, diarrhea, cholera, and other infectious diseases. Also, the poor lack the needed resources for healthcare. Finally, there are generally low adaptive capacities to cope with climate change. No insurance, no access to credit markets and unavailable institutional framework to help the poor cope with climate impacts. Very related to the above, the World Economic and Social Survey (2016) reports that in countries where there is widespread poverty, the poor suffer disproportionately more from climate hazards not only because of their poverty status but also because of their unequal standing in society. Brugnach, Craps and Dewulf (2017) argue that the poor and the marginalized are the most vulnerable to extreme weather events and rising temperatures mainly because they lack the necessary resources to adapt to it. Evidence (FAO, 2017) indicates that the heavy rains that flooded Mumbai, India in 2005 affected poor households twice as much as it affected others. Similarly, poor people lost thrice as much as others when hurricane Mitch occurred in Honduras in 1998. They also alluded to the fact that the poor reside in risk exposed areas and have fewer resources to adapt, buffer and recover quickly from shocks.

More recently, UNDESA (2020) affirms that climate change affects the prevalence and depth of poverty, and if left unchecked will contribute to income inequality both within and between countries. Climate change affects the resources and assets that aid the poor to generate income. The wealth of the poor is more affected by climate change because their wealth is concentrated in houses and livestock which are more fragile.

4.2.2 Empirical literature on Climate change, Weather events and Inequality

Literature is generally in high dearth when it comes to climate change and income inequality. The very few available and accessible ones are discussed in this section. A study by Burges, Deschenes, Donaldson and Greenstone (2014) on the unequal effects of weather and climate change with evidence from mortality in India used district-level panel data to test whether hot weather shocks have unequal effects on mortality in both rural and urban populations. They mentioned that this effect to a large extent depends on the degree to which incomes are affected by weather shocks. Their findings revealed that a rise in high-temperature days by one standard deviation within a year causes a decrease in agricultural productivity and real wages among the rural population but has no effect among the urban population. Otrachshenko and Popova (2019) used regional panel data from Russia and showed the effect that extreme weather (hot temperature and cold temperature) has on income inequality. Their findings reveal that extremely hot temperatures affect income distribution and worsen income inequality in poorer regions while having minimal impact on rich regions. The study explains that extremely hot temperatures reduce employment in private sector industries while increasing employment in the low-paid public sector.

More recently, Diffenbaugh and Burke (2019) find that there is a high likelihood of an anthropogenic climate to exacerbate income inequality among countries. The study mentions that the increase in inequality between countries is a result of global warming induced-penalties in poor nations along with warming-induced benefits in rich countries. They estimate the parabolic relationship between temperature change and economic growth and find long term global warming to increase growth in cold countries (such as Norway) but decrease growth in warm countries (such as India). Quite related to this study is the paper by Dasgupta, Emmerling and Shayegh (2020) who investigates the impact of climate change on income distribution and income inequality in South Africa using global, regional and household-level panel data. Their findings show that inequality and poverty have a U-shaped relationship with temperature while that between temperature and GDP or income per capita shows an inverted U-shaped relationship. They argue that these relationships hold for global macro aggregates and micro household inequality data. Their findings imply that substantial increases in inequality are projected at higher temperatures.

4.2.3 Climate change and Agricultural Production

Barrios, Ouattara and Strobl (2008) examine the impact of climate change on agricultural production in Sub-Sahara Africa and other non-Africa developing countries. Measuring climate change as changes in country-wide rainfall and temperature, the study finds that decreases in rainfall and temperature change reduce agricultural output in sub-Sahara Africa while having a minimal impact in non-Sub-Sahara developing countries. Dell et al. (2012) find that one degree celcius higher temperature is associated with a 2.66 percentage points reduction in the growth of agricultural output in poor countries but find an insignificant result for rich countries.

Auffhammer and Schlenker (2014) argue that agricultural productivity heavily depends on weather outcomes since the weather is considered a direct input in the agricultural production function and hence climate change has a great potential to cause a major upset in the agricultural sector. This finding is based on both reduced form studies as well as integrated assessment models. Similar thoughts are shared by Calvin et al. (2020) using the Global Integrated Assessment Model (GCAM). Also, Burgess et al. (2014) find that agricultural yield reduces, and the wage of agricultural labourers also reduce in the presence of hot weather especially during planting seasons.

FAO (2018) asserts that climate variabilities have both direct and indirect effects on agricultural yields, aquaculture, livestock, and fisheries production. Statistically, FAO (2017) also estimates that 25 percent of the hazards caused by natural disasters affect agriculture and the agricultural sector also absorbs 80 percent of the damages and loss caused by droughts. Finally, UNDESA (2020) argues that indigenous people and small landholders are more exposed to climate change because most of these people depend on agriculture, fishing and other ecosystem income-generating activities.

4.2.4 Empirical determinants of income inequality

Literature is not in dearth when it comes to the empirical determinants of inequality. Few of the sampled but relevant studies that focused on inequality drivers are discussed in this section. Dabla Norris et al. (2015) came out with a study on the global causes and consequences of income inequality in 100 advanced and emerging markets and developing countries and find that a number of inter-related factors can affect inequality and these factors may have differential effects depending on the country and income group. The following factors are identified to affect inequality; skill premium, financial globalisation, labour market regulations, government spending, technology, financial deepening and female mortality rate. The paper by Anyanwu (2016) on the main drivers of inequality in Southern Africa finds gross capital formation, GDP per capita, the squared term of political globalization, population growth and the first lag of income inequality to positively and significantly influence inequality. On the other hand, he finds the squared term of GDP per capita, political globalization, secondary school enrolment, total resource rent and the second lag of inequality to negatively affect income inequality.

Similarly, Anyanwu et al. (2016) find the following as the main drivers of income inequality in West Africa; the first two period lags of inequality, GDP per capita, squared term of GDP per capita, FDI inflows, resource rent, population density, secondary school enrolment, gross capital formation, trade openness, government expenditure, remittances received, democracy, civil war, unemployment rate, political and social globalization. A working paper by Cevik and Correa-caro (2015) conducted a study on the proximate determinants of inequality with a particular focus on the distributional impacts of fiscal policy. The paper concentrated on Brazil, Russia, India, China (BRIC) and other 30 emerging market economies. They find only the previous year's inequality, per capita GDP and its square to be significant. Government expenditure and tax which are used as proxies for fiscal policy remain insignificant in addition to trade openness, financial development, index of human capital and the share of the urban population. The fiscal policy variables of taxation and government spending were found to be statistically significant in China with taxation serving as a redistributive tool while government spending increases inequality. Lastly, Jaumotte, Lall and Papageorgiou (2013) examine the relationship between technology, trade, or financial globalization on income inequality in 51 advanced and developing countries and find a greater impact for technological progress than for globalization. They include controls such as access to education, shares of employment in agriculture and industry and domestic financial development.

4.2.5. Summary of Literature and Gaps

There is vast amount of literature that have focused on why climate change and extreme weather events affect the poor more disproportionately. However, empirical evidence on the effect climate change and weather events have on income inequality remain worth exploring due to limited number of studies. The few studies that attempt these focused on between-country inequality or climate change measured mostly by temperature. These studies mostly ignore weather events, within-country income inequality and African countries. This study therefore focuses on the relationship between within-country income inequality and weather-related events in African countries. In addition, the study delves into the roles institutions and adaptive capacities play in modulating the effects of weather events on income inequality.

4.3. Methodology

4.3.1 Model specification, definition & measurement of variables and a priori expectations

The model specification of this study follows recent income inequality studies (see Kunawotor et al., 2020; Adeleye et al., 2017; Anyanwu et al., 2016) where income inequality is predicted by inequality in previous year, explanatory variables and some control variables. The lag of income inequality is introduced because income inequality is known to be persistent and hence changes at a slow pace. That is, the previous year(s) income inequality affects the current level. The past income inequality is an unbiased predictor of the current income inequality. This model, therefore, take the form;

Model 1: The Effects of Weather Events & Flood on Income Inequality

$$Inequality_{it} = \alpha_1 Inequality_{it-1} + \alpha_2 WeatherEvents_{it} + \beta' X_{it} + \mu_i + \mu_t + \varepsilon_{it} \quad \text{....... (1)}$$

Model 2: The Moderating effects of Institutions & Adaptive capacity on Income Inequality

$$Inequality_{it} = \sigma_1 Inequality_{it-1} + \sigma_2 WeaEvent_{it} + \sigma_3 Inst_{it} + \sigma_4 (WeaEvent_{it} * Inst_{it}) + \beta' X_{it} + \varpi_i + \varpi_t + \upsilon_{it} \quad \text{..... (2a)}$$

$$Inequality_{it} = \theta_1 Inequality_{it-1} + \theta_2 WeaEvent_{it} + \theta_3 Adapcap_{it} + \theta_4 (WeaEvents_{it} * Adapcap_{it}) + \beta' X_{it} + \eta_i + \eta_t + \lambda_{it} \quad \text{.... (2b)}$$

Model 3: The Indirect effects of Weather events & Flood on Income Inequality through Agricultural Productivity

$$Inequality_{it} = \phi_1 Inequality_{it-1} + \phi_2 WeatherEvents_{it} + \phi_3 AgricProductivity_{it} + \beta' X_{it} + \pi_i + \pi_t + \theta_{it} \quad \text{... (3)}$$

Income inequality ($Inequality_{it}$) is the dependent variable in all the models and it is measured using the market Gini index developed by Solt (2019). The market Gini index estimates inequality using equivalized household market (pre-tax, pre-transfer) income. The index ranges from 0 to 100 with 0 indicating perfect equality while 100 indicates perfect inequality. The within-country Gini coefficient measures the income distribution or consumption among households in a country. The letter 'i' and 't' represent a given country and year respectively. $Inequality_{it-1}$ represents income inequality in a given country in the previous year. It is expected that past levels of inequality will drag current levels of inequality and hence exhibiting a great degree of inertia.

The main independent variable is weather event ($WeatherEvents_{it}$). 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. 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, a hundred (100) or more people reported affected, a declaration of a state of emergency, a call for international assistance. This paper's classification of weather events follows exactly this criterion which is used by EM-DAT under disaster sub-group climatological, hydrological or meteorological. Generally, the paper expects weather events to widen income inequality as poor households tend to be more affected by these occurrences.

The main types and sub-types of weather events in Africa over the sample period are flood, drought, storm, landslide, wildfire, extreme temperature, heatwave, cold wave, land fire, forest fire, tropical cyclone and mudslide. This study, therefore, attempt to find out which of these occurrence (s) is likely to directly or indirectly affect income inequality. Flood and drought are the most frequent and hence their effects on inequality are considered. Flood and drought are also measured as count variables just like weather events so long as they are considered and entered by EM-DAT. It is also expected that either flood or drought will increase income inequality.

In Model 2, equation (2a & 2b), the paper attempts to find how adaptive capacity (Adaptivecapacity) and institutions ($Institutions_{it}$) moderate the linkage between weather events and income inequality. Institution is measured, following the approach by Kaufmann, Kraay and Mastruzzi (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 institutions. The paper expects strong institutions to reduce the impact of weather events on inequality and weak institutions to depict a converse effect. Also, adaptive capacity measured by the 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 – 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 inequality.

Agricultural productivity ($Agricultural\ Productivity_{it}$) is computed as an index using data of crop yield and livestock yield. An alternative measure is the net agricultural production value computed by the Food and Agricultural Organisation (FAO). We expect agricultural productivity to serve as a mediator through which weather events and the types may impact inequality. Thus, weather events such as floods and droughts could cause crop failure and affect the already marginalized.

The control variables are represented by a vector (X_{it}). These control variables include real GDP per capita and its square term, democracy, trade openness, resource rent, foreign direct investment, age dependency ratio, population growth rate, school enrollment rate and gross capital formation.

Real Gross Domestic Product (GDP) per capita is measured by taking the natural log of constant GDP per capita. Also, the paper introduces the square of real GDP per capita. It is expected that real GDP per capita will increase inequality in the short term and decrease it in the long term.

School enrollment is measured by the gross secondary school enrollment rate. As a measure of human capital development, the study expects a higher enrollment rate to decrease income inequality in Africa all things being equal. It also expects a positive relationship between population growth rate and inequality.

Trade openness is measured as the sum of total export and total imports scaled by GDP. It expects a negative relationship with inequality as trade liberalization opens more opportunities for employment of low skilled and low-income earners. Similarly, foreign direct investment (FDI) is measured as the net inflow of foreign direct investments as a ratio of GDP. It also expects a negative relationship with inequality.

Natural resource rents depict the extent to which a country relies on natural resources for development and we proxy natural resource rents as a percentage of GDP. It is expected that these resources will reduce income inequality when applied well, all things being equal. Similarly, capital formation as a percentage of GDP proxies the usage of physical capital in production. This is expected to generate more jobs and higher earnings and hence the potential to reduce income inequality.

Age dependency ratio is measured as the sum of the proportion of the young age population (0 - 15 years) and the old age population (65 years and above) to the working-age population (16 – 64 years). The paper expects a higher dependency ratio to translate to a low income per capita and hence a higher income inequality.

Finally, democracy is proxied by the polity2 index and it ranges from -10 to 10 with higher values indicating a high level of democracy in a country while lower values indicate autocracy. The paper expects democracy to reduce inequality as there is a guaranteed fair share of the national cake.

Finally, u_i, $\varpi_{i,}$ π_i and η_i represent the country fixed effects while u_t, ϖ_t, π_t and η_t represent the time fixed effects. Also, $\varepsilon_{it,}$ $\lambda_{it,}$ θ_{it} and υ_{it} represent the idiosyncratic error terms.

4.3.2 Sources of data and Scope of the study

The data used in this study is panel data and it includes 52 countries in Africa over the period 1990 – 2017. The income inequality data is gleaned from the Standardized World Income Inequality Database (SWIID) developed by Solt (2019) at the United Nations University World Institute for Development Economics Research (UNU-WIDER). Data from SWIID is more preferable as it collates data with comparable figures across various countries over a relatively long period of time. Data on weather event is 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. This data is sourced mainly from the United Nations, non-governmental organisations and governmental agencies, research institutes, insurance companies and press agencies. Data on institution is from Kaufmann, Kraay, & Mastruzzi (2011) while that of adaptation index is from Notre Dame Global Adaptation Index. The components of agricultural productivity and net agricultural production index are sourced from the Food and Agricultural Organisation (FAO). Data on democracy (polity 2) is taken from Marshall's Polity IV Project. The other variables including per capita GDP, FDI, age dependency ratio, gross capita formation, resource rent, trade openness, school enrollment and population growth are all taken from the World Bank World Development Indicators (WDI).

4.3.3. Estimation Technique

This study opted for the two-step difference Generalized Method of Moments (GMM) estimation approach and the Quantile regression technique. The use of GMM is justified by four main motives following recent GMM-centered literature (Kunawotor et al., 2020; Asongu et al., 2019; Tchamyou et al., 2019; Fosu & Abass 2019). (1) The number of cross sections (N) outweighs the time series (T). While the countries are 52, the time is 28 years. (2) A panel dataset is used and GMM as the estimation strategy accounts for differences across countries in the estimation process. (3) GMM also addresses endogeneity issues in two main ways; first, it accounts for unobserved heterogeneity using time-invariant omitted variables. Secondly, it produces internal instruments to account for reverse causality. Reverse causality exist as environmental degradation activities that lead to weather events can be caused by low income groups who usually depend on the environment for survival. This means that income inequality can cause weather events and vice versa. (4) Some empirical studies have identified inequality as persistent and hence it depends on its previous years' level. (see Asongu et al., 2020; Shimeles and Nabassaga, 2018; Anyanwu et al., 2016; Cevik and Correa, 2015). The estimation technique is robust to several checks including the Hansen test and the Arellano–Bond test for autocorrelation. All these tests proved satisfactorily. The bootstrap simultaneous quantile regression estimation technique is also used to determine if the impacts of weather events on income inequality vary at different distributions of income inequality. The quantile regression detects and controls for outliers and its usage is consistent with recent development literature (see Altunbas &Thornton, 2019; Asongu & Nwachukwu, 2016; Asongu, 2014).

4.4. Results

4.4.1 Descriptive statistics, Frequency distributions and Correlation matrix

The summary statistics in Table 4.1 shows the various distributions of the variables used in the study. Income inequality measured by market Gini has a mean score of 48.254. Income inequality generally appears quite high in the African continent relative to other continents as shown in Figures 4.1 & 4.2. In terms of the regional distributions in Africa, inequality is much higher in southern Africa (59.0659), than West Africa (46.03594), East Africa (45.38987) and the least being Northern Africa (42.49917). Weather events have a 93 percent probability of occurring within a year in an African country. The study further tabulates 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 4.2. Out of a total of 1,456 outcomes, weather events have occurred 53 percent of the time for at least once in a year. Out of these occurrences, weather events have 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.

In terms of weather events types, flood and drought have 58 percent and 21 percent probability of occurring in a year in Africa. Since floods have been more frequent than the other types of weather events, its distribution just like weather events is shown in Table 4.2. The mean of institutions (-.628) shows that institutions are generally weak in Africa. The same applies to adaptive capacity which has a paltry mean of 37 out of 100. Most African countries are also at the budding stage of democracy as shown by the mean of 0.616. There is generally no concern for multicollinearity in the models as shown by the matrix of correlations in Table 4.3 and also evident in the variance inflation factor (vif) presented in Table 4.4 as none of the vifs exceeds 10.

Table 4. 1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Inequality – Market Gini	986	48.254	7.921	33.7	70.7
Weather Events	1456	.931	1.229	0	9
Flood	1456	.581	.913	0	7
Drought	1456	.205	.419	0	2
Agricultural Productivity	1122	.026	1.778	-2.072	9.341
Trade openness	1251	.693	.35	.191	3.762
Resource rent	1423	12.263	12.336	0	84.24
Polity2	1345	.616	5.658	-10	10
Adaptive capacity	1173	37.237	6.358	25.238	55.918
Institutions	988	-.628	.588	-2.1	.88
Dependency ratio	1450	84.509	15.633	41.293	112.849
FDI	1388	4.036	9.132	-8.589	161.824
Per capita GDP	1390	2211.006	2926.692	164.337	20512.941
Gross capital formation	1293	21.575	9.888	-2.424	85.101
Population growth rate	1450	2.379	1.085	-6.766	8.118
Secondary school enrollment	862	41.225	25.644	5.221	115.957

Table 4. 2: Weather Events Tabulation from 1990 - 2017

Weather Events			Flood		
Variable count	Frequency	Percent	Variable Count	Frequency	Percent
0	689	47.32	0	889	61.10
1	435	29.88	1	378	25.98
2	191	13.12	2	131	9.00
3	76	5.22	3	37	2.47
4	36	2.47	4	14	0.96
5	18	1.24	5	1	0.07
6	5	0.34	6	5	0.34
7	2	0.14	7	1	0.07
8	3	0.21	8	--	--
9	1	0.07	9	--	--
Total	1,456	100	Total	1,456	100

Source: Authors construct (2020) from EM-DAT data

Table 4. 3: Matrix of correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) Inequality_Gini	1.000										
(2) Weather Events	0.008	1.000									
(3) Real GDP	0.186	-0.160	1.000								
(4) Democracy-polity2	0.313	0.180	-0.009	1.000							
(5) Trade openness	0.076	-0.141	0.357	0.101	1.000						
(6) FDI	-0.046	-0.060	0.040	0.019	0.300	1.000					
(7) Age dependency	-0.086	0.102	-0.627	-0.148	-0.356	-0.033	1.000				
(8) Population growth	-0.168	0.103	-0.172	-0.032	-0.202	0.094	0.450	1.000			
(9) School enrollment	0.205	-0.094	0.687	0.245	0.291	0.024	-0.812	-0.501	1.000		
(10) Gross capital	-0.002	-0.009	0.273	0.084	0.343	0.292	-0.276	-0.006	0.176	1.000	
(11) Resource rents	-0.288	0.004	0.169	-0.216	0.168	0.219	0.098	0.269	-0.208	0.076	1.000

Table 4. 4: Variance Inflation Factor (VIF)

	VIF	1/VIF
School enrollment	4.882	.205
Age dependency ratio	4.617	.217
Real GDP per capita	2.702	.37
Population growth	1.98	.505
Trade openness	1.577	.634
FDI	1.459	.685
Gross capital formation	1.382	.724
Total natural resource rent	1.242	.805
Democracy	1.212	.825
Weather Events	1.118	.894
Mean VIF	2.217	.

4.4.2 Empirical results of the Effects of Weather Events and Flood on Income Inequality

The results of the GMM estimates in Table 4.5 show that there is a non-monotonic U-shape relationship between weather events and income inequality. Thus, lower counts of weather events cause a reduction in income inequality while further occurrence within the same fiscal year causes an increase in income inequality. This is shown in Model 1 and Model 2. In Model 1, the linear form of weather events is negative (-0.025) and statistically significant. However, with the introduction of the square of weather events in Model 2 along with its linear term, the linear term maintains the negative sign (-0.034) and also remains statistically significant while the squared term produces a positive (0.003) and statistically significant nexus with income inequality. This presupposes that weather events have a non-monotonic U-shaped effect on income inequality. Thus, a higher frequency of weather events beyond a certain threshold actually causes income inequality to increase. Also, lower counts tend not to have detrimental effect on inequality.

The findings also reveal that the turning point for this U-shape effect occurs at the sixth count of the occurrence of weather events within a fiscal year in Africa. The turning point is computed by taking the partial derivative of equation 3 which amounts to the linear form divided by two times the squared form. This is computed from Model 2 as 5.911 = - (-0.0344)/2 x 0.00291)). This U-shape effect corroborates the recent finding of temperature change effects on inequality in South Africa by Dasgupta et al. (2020). In furtherance of the above and more intriguingly, the result of the bootstrap quantile regression technique in Table 4.6 clearly shows that the occurrence of weather events actually increases income inequality. The income inequality-increasing effect of weather events occurs at all levels of the income inequality distribution including the lower and mid-quantiles (i.e. 10^{th}, 25^{th}, 50^{th}, and 75^{th} percent quantiles) except for the upper tail of the distribution (90th percent quantile). It should be noted, however, that only the 25th percent quantile and 50th percent quantile appear statistically significant and these are shown in Model 6 and Model 7 respectively. The 10th quantile and 75th quantile although have positive signs appear statistically insignificant in Model 5 and Model 8. Thus, weather events affect the poor more disproportionately at lower and mid-levels of the income distribution.

The probable intuition and implication of weather events causing an increase in income inequality is that a greater reliance on weather-dependent forms of production will cause households to experience larger income shocks upon happenings of weather events as alluded to by Burges et al. (2014) and UNDESA (2020). Thus, weather events may widen income inequality because the economically poor and the marginalized are more disproportionately affected by weather events making them poorer and this tends to widen the income inequality gap. This may be because they depend more on climate-sensitive activities such as agriculture for their source of livelihoods and as such a little disturbance may tend to be a destabilizer.

Another plausible explanation according to UNDP (2016) and Ludwig et al. (2007) is that richer households can afford to buy insurance which minimizes or mitigates the impact of weather events on their incomes through compensation packages, poorer households may not be able to afford such insurance packages further widening the income inequality gap. Also, the poor are mostly found in semi-arid regions which are more prone to weather events such as floods and droughts due to the erratic climate nature of such environments which makes weather events almost unpredictable.

Interestingly, when the paper attempt to find which of these weather events types have a statistically significant impact on income inequality, it found the occurrence of floods to follow the same pattern as weather events. The findings reveal that the incidence of flood also has a non-monotonic effect on income inequality and this is shown in Model 4. The form also takes a U-shape and the turning point occurs at the third occurrence of flood within a fiscal year. This is computed from Model 4 as 3.155 = - (-0.0424/2 x 0.00672). Intuitively, poor households and those who live in flood-prone areas and occupy houses made of flimsy materials with poor drainage systems are more susceptible than those who live in sturdy houses and this may further widen the income inequality gap. The paper did not find other disaster types such as drought, to have any significant effect on income inequality (results not shown here). This may probably be so because floods have occurred more frequently in Africa than the other types of weather events types as shown in the summary statistics.

Consistent with the usage of the GMM model, the past level of income inequality is positive and statistically significant in all the models (Model 1 – Model 4) signifying the persistence of income inequality. Persistency is also evident in our data as the correlation between income inequality and its first lag is 0.9995 and this exceeds the threshold of 0.8 necessary to justify the persistence of an outcome variable. All these justify the persistent nature of income inequality and hence higher income inequality levels in the past may drag current levels from falling.

School enrollment as a measure of skill premium and human capital development has a negative and statistically significant effect on inequality in Model 1 – Model 3. This means that the diffusion of human capital among the populace in Africa may empower households economically and this may help reduce the income inequality gap. That is, as more people become enlightened through our educational systems, their skill set is enhanced and a greater propensity to acquire a job or reduce the earnings gap between the highly-skilled and unskilled.

This finding is in line with the findings of Anyanwu (2016) for Southern African countries, Anyanwu et al. (2016) for West Africa, Dincer and Gunalp (2012) for the United States.

The study also finds natural resource rent to be highly significant with a negative effect on income inequality in all the Models. (Model 1 – Model 4). African countries can leverage on the abundance and dependence on natural resources to help poor households catch up on the income and wealth ladder lending support to the findings of Anyanwu (2016) but contradicts that of Anyanwu et al (2016).

Similarly, the paper finds gross capital formation which proxies for domestic capital investment to have a negative and significant effect on inequality in Africa which confirms the findings of Kunawotor et al. (2020) in Africa and Lee et al. (2013) in Korea but contradicts that of Anyanwu (2016) and Anyanwu et al. (2016) in South and West Africa respectively. This finding is in line with the a priori expectations and the implication is that, as more domestic investments are made, it creates more employment and earnings opportunities for the less privileged hence reducing the income inequality gap. The Age dependency ratio contrary to the study's expectation rather appears to reduce inequality.

Finally, among the set of controls, the paper finds democracy to have a negative and statistically significant effect on income inequality. Countries that tend to practice democracy may see their inequality gap narrowing than those that lean towards autocracy probably because of equity and fair distribution.

All the other variables including per capita GDP, FDI, population and trade openness remain statistically insignificant.

Table 4. 5: The Effects of Weather Events & Flood on Income Inequality – GMM

VARIABLES	MODEL 1	MODEL 2	MODEL 3	MODEL 4
Lag of Income Inequality	0.859***	0.893***	0.856***	0.898***
	(0.039)	(0.034)	(0.044)	(0.037)
Weather Events	**-0.025****	**-0.034****	--	--
	(0.010)	(0.014)		
Weather Events - Squared	--	**0.003***	--	--
		(0.002)		
Flood	--	--	**-0.026****	**-0.042*****
			(0.013)	(0.014)
Flood - Squared	--	--	--	**0.007****
				(0.003)
GDP per capita	0.063	-0.357	0.035	-0.510
	(1.335)	(1.137)	(1.371)	(1.193)
GDP per capita^2	0.022	0.048	0.026	0.059
	(0.087)	(0.075)	(0.088)	(0.079)
Democracy - polity2	-0.019*	-0.012	-0.020*	-0.010
	(0.009)	(0.007)	(0.011)	(0.007)
Trade openness	-0.115	-0.074	-0.109	-0.055
	(0.218)	(0.173)	(0.227)	(0.174)
FDI	0.007	0.006	0.007	0.006
	(0.006)	(0.003)	(0.006)	(0.004)
Dependency ratio	-0.016**	-0.009*	-0.016**	-0.008
	(0.007)	(0.005)	(0.008)	(0.006)
Population	0.037	0.025	0.039	0.024
	(0.038)	(0.025)	(0.039)	(0.024)
Gross school enrollment	-0.015**	-0.009*	-0.015**	-0.009
	(0.006)	(0.006)	(0.006)	(0.006)
Capital formation	-0.008**	-0.009***	-0.008**	-0.009***
	(0.003)	(0.002)	(0.003)	(0.003)
Resource rent	-0.016***	-0.014***	-0.017***	-0.014***
	(0.005)	(0.005)	(0.006)	(0.005)
Constant	7.419	6.708	7.533	6.814
	(4.703)	(4.797)	(4.727)	(5.099)
Observations	472	472	472	472
Number of countries	40	40	40	40
Number of instruments	14	25	14	25
Wald test of joint sign (P- value)	0.000	0.000	0.000	0.000
Arellano-Bond test for AR(1):(Pr > z)	-3.21(0.001)	-2.98(0.003)	-2.81(0.005)	-2.79(0.005)
Arellano-Bond test for AR(2):(Pr > z)	0.03(0.978)	0.09(0.928)	0.09(0.925)	0.16(0.874)

Sargan test of overid: (Prob > chi2)	0.36(0.546)	7.63(0.746)	0.42(0.516)	8.50(0.668)
Hansen test of overid: (Prob > chi2)	0.42(0.517)	7.82(0.729)	0.49(0.485)	7.92(0.721)

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 NB: Model 1 shows the effect of weather events on inequality, Model 2 is just a replica of Model 1 with the exception of the addition of the squared term of weather events. Model 3 shows the effect of flood on inequality while Model 4 introduces the squared term of flood.

Table 4. 6: The Effects of Weather Events on Income Inequality – Quantile Regression

VARIABLES	MODEL 5	MODEL 6	MODEL 7	MODEL 8	MODEL 9
QUANTILES	0.10	0.25	0.50	0.75	0.90
Weather Event	**0.114**	**0.409****	**0.293***	**0.083**	**-0.013**
	(0.161)	(0.196)	(0.154)	(0.185)	(0.144)
Real GDP per capita	14.35***	14.51***	7.228	-54.27***	-49.83***
	(3.941)	(3.857)	(10.52)	(7.008)	(11.74)
Real GDP per capita^2	-1.021***	-1.077***	-0.472	4.143***	3.700***
	(0.267)	(0.256)	(0.822)	(0.466)	(0.847)
Democracy - polity2	-0.072*	-0.085**	0.079	0.232***	0.310***
	(0.037)	(0.037)	(0.091)	(0.069)	(0.074)
Trade openness	0.934	3.538***	2.149	-2.031*	0.901
	(1.085)	(1.184)	(1.844)	(1.097)	(1.976)
FDI	-0.006	-0.011	0.072	0.088**	-0.038
	(0.054)	(0.063)	(0.052)	(0.045)	(0.054)
Dependency ratio	0.036	0.116*	0.285***	0.280***	-0.020
	(0.046)	(0.063)	(0.043)	(0.054)	(0.081)
Population growth	-0.098	-0.112	-1.661*	-1.628*	-0.726**
	(0.383)	(0.557)	(1.006)	(0.860)	(0.328)
Second' school enrollment	0.006	0.055*	0.119***	0.043	-0.065**
	(0.022)	(0.033)	(0.024)	(0.031)	(0.026)
Capital formation	-0.101***	-0.043	-0.026	-0.046	-0.012
	(0.035)	(0.047)	(0.044)	(0.041)	(0.038)
Resource rent	-0.163***	-0.175***	-0.185***	-0.158***	-0.207***
	(0.038)	(0.041)	(0.051)	(0.033)	(0.032)
Constant	-7.283	-15.92	-4.536	206.6***	226.4***
	(16.20)	(13.89)	(32.37)	(28.22)	(35.67)
Observations	501	501	501	501	501
Pseudo R^2	0.225	0.169	0.145	0.297	0.467

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

4.4.3 Results of the Moderating role of Institutions, its sub-components and Adaptive Capacity on Income Inequality

The findings reveal that African countries with relatively strong institutions do not incur the full wrath of weather events when it occurs. Stronger institutions may help reduce the impact of weather events on income inequality. This finding can be observed in the negative interactive term between weather events and institutions (-0.0252) and more importantly, in the net negative effect (-0.02074) in Model 10 as shown in Table 4.7. A look at the sub-components that make up the institution index reveals that control of corruption, political stability and absence of violence, and voice and accountability independently help significantly moderate the relationship between weather events and income inequality. This is so as the paper finds both the interactive terms and net effects to be negative in all three of these instances as shown in Model 11, Model 12 and Model 13 respectively. Countries with stronger institutions have less corruption, are more politically stable and have strong mechanism for voice and accountability and hence these systems are able to lessen the burden of weather events on the poor who tend to be more disproportionately affected. For example, when a weather event like flooding occurs, if there are strong systems to control corruption, the relief items will get to the affected persons like the poor and this will lessen the effects on them and not impoverish them more. However, there appears to be no significant effect for the other three components of institutions including government effectiveness, rule of law and regulatory quality (results not shown here). Also, there is no statistically significant moderating effect of adaptive capacity on income inequality at the occurrence of weather events even though it is the papers expectation that countries that have put in place strong adaptive mechanisms against climate events will experience less of these impacts. This result is shown in Model 14.

Table 4. 7: The moderating role of institutions and adaptive capacity on inequality

VARIABLES	MODEL 10	MODEL 11	MODEL 12	MODEL 13	MODEL 14
Lag of Income Inequality	0.884***	0.885***	0.874***	0.877***	0.886***
	(0.029)	(0.030)	(0.030)	(0.037)	(0.028)
Weather Events	-0.037***	-0.037***	-0.041***	-0.034***	-0.000
	(0.013)	(0.014)	(0.012)	(0.011)	(0.036)
Institutions	-0.078	--	--	--	--
	(0.225)				
Events - Institutions	**-0.025***	--	--	--	--
	(0.014)				
Control of corruption	--	-0.096	--	--	--
		(0.176)			
Events - Corruption	--	**-0.023***	--	--	--
		(0.013)			
Political stability	--	--	0.027	--	--
			(0.088)		
Events – Pol' stability	--	--	**-0.023*****	--	--
			(0.008)		
Voice & Accountability	--	--	--	0.023	--
				(0.116)	
Events - Voice & Acc'	--	--	--	**-0.023****	--
				(0.010)	
Adaptive capacity	--	--	--	--	-0.048**
					(0.022)
Events – Adap capacity	--	--	--	--	**-0.000**
					(0.001)
GDP per capita	0.688	0.728	0.467	0.647	0.897
	(1.786)	(1.737)	(1.950)	(2.142)	(1.167)
GDP per capita^2	-0.029	-0.029	-0.011	-0.026	-0.031
	(0.114)	(0.114)	(0.124)	(0.139)	(0.079)
Polity2	-0.017**	-0.017**	-0.016**	-0.016	-0.013**
	(0.007)	(0.006)	(0.006)	(0.013)	(0.006)
Trade openness	-0.132	-0.154	-0.153	-0.143	-0.067
	(0.181)	(0.179)	(0.196)	(0.193)	(0.165)
FDI	0.008*	0.008*	0.009	0.009	0.008*
	(0.004)	(0.005)	(0.006)	(0.006)	(0.004)
Dependency ratio	-0.004	-0.003	-0.006	-0.005	-0.013
	(0.009)	(0.009)	(0.009)	(0.009)	(0.008)
Population growth	0.006	0.007	0.006	0.005	0.055
	(0.069)	(0.078)	(0.072)	(0.069)	(0.056)
School enrollment	-0.007	-0.008	-0.008	-0.008	-0.009
	(0.007)	(0.008)	(0.008)	(0.009)	(0.007)

Capital formation	-0.007**	-0.007**	-0.008**	-0.007**	-0.009***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Resource rents	-0.014***	-0.014***	-0.013***	-0.013***	-0.015***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Constant	3.133	2.728	4.471	3.773	4.079
	(6.284)	(6.217)	(7.404)	(8.416)	(4.250)
Net Effects	**-0.021**	**-0.023**	**-0.029**	**-0.020**	--
Observations	347	347	347	347	413
Number of Countries	40	40	40	40	39
Number of Instruments	18	18	18	18	18
Wald test (P- value)	0.000	0.000	0.000	0.000	0.000
Arellano-Bond: AR(1)	-2.13(0.033)	-2.12(0.034)	-2.07(0.039)	-2.34(0.020)	-3.02(0.003)
Arellano-Bond: AR(2)	-0.04(0.972)	-0.14(0.885)	-0.21(0.834)	-0.18(0.860)	-0.01(0.991)
Sargan test of overid	4.81(0.186)	5.36(0.147)	5.07(0.167)	5.17(0.160)	1.69(0.640)
Hansen test of overid	2.04(0.564)	2.25(0.521)	2.09(0.555)	1.93(0.588)	1.13(0.769)

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 NB: Model 10 estimates the moderating role of institutions. Model 11, 12 & 13 show the moderating roles of the sub-component of institution which are control of corruption, political stability and, voice and accountability respectively. Model 14 shows the moderating role of adaptive capacity on inequality.

4.4.4 Empirical Result of the Mediating role of Agricultural Productivity

Weather events may not only affect income inequality directly but may also do so through its effects on agricultural productivity. In this regard, the paper attempts to find if agricultural productivity may serve as a conduit for weather events to impact income inequality. The study does this by estimating the effect of weather events on income inequality without agricultural productivity and then afterwards it introduces agricultural productivity in the same model with weather events. Weather events appears statistically significant as shown in Model 15 in Table 4.8 but the paper does not find any significant mediating role of agricultural productivity as it appears statistically insignificant in Model 16 when introduced in addition to weather events.

The same is done for flood and drought (result for drought not presented here) in Model 18 and find a similar insignificant outcome for agricultural productivity even though flood by itself has a significant impact on income inequality in Model 17. These outcomes are also not significant when the study estimated for Sub-Sahara Africa, West Africa, East Africa and Southern Africa countries independently. These findings imply that weather events and its types such as flood and drought may have a negative impact on agricultural productivity by reducing agricultural yield as experienced in some parts of Africa and this may affect income inequality but these impacts do not appear statistically significant in this study.

Table 4. 8: The Indirect effects of Weather events & Flood on Inequality through Agricultural Productivity

VARIABLES	MODEL 15	MODEL 16	MODEL 17	MODEL 18
Lag of Income Inequality	0.859***	0.864***	0.856***	0.858***
	(0.039)	(0.055)	(0.044)	(0.064)
Weather Event	-0.025**	-0.021*	--	--
	(0.010)	(0.012)		
Agricultural productivity	--	0.006	--	0.008
		(0.048)		(0.051)
Flood	--	--	-0.026**	-0.023
			(0.013)	(0.014)
GDP per capita	0.063	0.069	0.035	0.082
	(1.335)	(1.795)	(1.371)	(1.875)
GDP per capita^2	0.022	0.020	0.026	0.022
	(0.087)	(0.124)	(0.088)	(0.128)
Polity2	-0.019*	-0.018	-0.020*	-0.018
	(0.009)	(0.011)	(0.011)	(0.012)
Trade openness	-0.115	-0.067	-0.109	-0.060
	(0.218)	(0.227)	(0.227)	(0.238)
FDI	0.007	0.008	0.007	0.008
	(0.006)	(0.006)	(0.006)	(0.007)
Dependency ratio	-0.016**	-0.017	-0.016**	-0.017
	(0.007)	(0.010)	(0.008)	(0.011)
Population growth	0.037	0.037	0.039	0.039
	(0.038)	(0.038)	(0.039)	(0.042)
School enrollment	-0.015**	-0.016**	-0.015**	-0.017**
	(0.006)	(0.006)	(0.006)	(0.007)
Capital formation	-0.008**	-0.009**	-0.008**	-0.009**

	(0.003)	(0.003)	(0.003)	(0.004)
Resources rent	-0.016***	-0.016**	-0.017***	-0.017**
	(0.005)	(0.006)	(0.006)	(0.007)
Constant	7.419	7.352	7.533	7.477
	(4.703)	(4.904)	(4.727)	(4.950)
Observations	472	436	472	436
Number of countries	40	38	40	38
Number of instruments	14	15	14	15
Wald test of joint sign (P- value)	0.000	0.000	0.000	0.000
Arellano-Bond: AR(1):(Pr > z)	-3.21(0.001)	-2.87(0.004)	-2.81(0.005)	-2.50(0.012)
Arellano-Bond: AR(2):(Pr > z)	0.03(0.978)	0.16(0.877)	0.09(0.925)	0.23(0.821)
Sargan test of overid	0.36(0.546)	0.51(0.475)	0.42(0.516)	0.51(0.477)
Hansen test of overid	0.42(0.517)	0.67(0.413)	0.49(0.485)	0.66(0.415)

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

4.5. Conclusion and Recommendations

Climate change and inequality remain a critical focus of world leaders as they are enshrined in the sustainable development goals. Weather events are the trickle-down effects of climate change as they appear much patterned in Africa due to their frequent occurrences and the damning consequences they come with, especially by affecting the marginalized poor and disproportionately widening the economic inequality gap. This study empirically examined the effects of weather events on income inequality and found a non-monotonic U-shape effect using GMM while the results of the quantile regression clearly show that weather events increase income inequality at lower and mid quantiles. The paper also found a very similar effect for weather events type, flood. In addition, it found institution and its components such as political stability and absence of violence, voice and accountability and, control of corruption to significantly moderate the relationship between weather events and income inequality. Finally, it does not find a moderating effect of adaptive capacity, neither did it find any mediating effect of agricultural productivity on income inequality.

The study recommends that critical attention should be paid to climate change mitigation as the impending future impacts of climate change in the form of weather events appear gloomy for major economic and social indicators such as income inequality. African countries should also build stronger institutions and put in place systems for adaptation against climate change impacts as institutions and adaptive capacities remain very weak.

CHAPTER FIVE

THE DISTRIBUTIONAL EFFECTS OF FISCAL AND MONETARY POLICIES IN AFRICA

Abstract

Income inequality has been persistent and indeed high in Africa over decades. Accordingly, a lot of empirical drivers have been identified to address it, albeit to the large neglect of fiscal and monetary policies in Africa. This paper provides new and comprehensive evidence on the distributional effects of both fiscal and monetary policies in Africa over the period 1990 – 2017. The paper employs a two-step dynamic system Generalized Method of Moments, a simultaneous quantile regression, a Panel VAR and also uses variants of fiscal and monetary indicators including fiscal redistribution. The results show that fiscal redistribution has been quite effective in Africa as reflected in the role played by income taxes and transfers in reducing Gini coefficients albeit to a relatively little extent. In particular, the paper finds that direct tax is progressive and a potent tool in redistributing income in favour of the have-nots. Indirect tax unsurprisingly is regressive and income unequalizing. Similarly, property taxes have income unequalizing effects in Africa. The results of the expenditure indicators reveal that government spending on basic and primary education narrows net income inequality while government spending on secondary and tertiary education rather widens net income inequality. Lastly, it finds that contractionary monetary policy has unintended distributional effects in Africa. The paper suggests that governments should broaden their tax net, increase the share of direct tax

including property tax and spend more on basic education to improve income distribution in Africa[4].

5.1 Introduction & Motivation

Ensuring equity in income distribution has been a topical research issue over decades and a central focus of many governments world-wide. Due to the high and persistent nature of income inequality globally, it is currently considered a defining challenge and in recent times, there is a growing public concern in many countries for governments to ensure that everybody gets a fair share of the national cake. The significance of reducing income inequality makes it imperative to be captured in the in the Sustainable Development Goals (SDGs).

It is worth noting that, ensuring equitable income distribution is imperative to achieving sustainable economic growth, macroeconomic stability, poverty reduction, and political stability (Anyanwu et al., 2016; OECD, 2015; Cojocaru & Diagne, 2014; Ostry, Berg & Tsangarides, 2014; IMF, 2014). Empirical evidence in Africa (see Shimeles and Nabassaga, 2018; Fosu, 2015) for instance suggests that no amount of growth in GDP per capita income would be sufficient to reduce extreme poverty without a corresponding decrease in income inequality. High levels of income inequality destroys social cohesion and this makes it challenging to gain public support for growth-enhancing reforms and may also cause political instability (Anyanwu, 2016; Claessens & Perotti 2007).

The key concern of this paper is to identify the appropriate policy tools which will be adequate to address the widespread economic disparity in Africa. African countries have the highest Gini coefficients worldwide, outperforming only Latin America and the Caribbean in the inequality

[4] An extract from this chapter has been published; Kunawotor, M. E., Bokpin, A. G. Asuming, O. P. & Amoateng, K. (2022). The Distributional Effects of Fiscal and Monetary Policies in Africa. *J. Soc. Econ. Dev. 24, 127–146.*

distribution table (UNDESA, 2019; Odusola, 2017; World Bank, 2016). Also, UNDP (2017) asserts that ten out of the world's nineteen most unequal countries are located in Africa. This notwithstanding, several empirical studies (see Kunawotor et al., 2020; Asongu et al., 2020; Shimeles and Nabassaga, 2018; Adeleye et al. 2017; Anyanwu, 2016) have unmasked income inequality as highly persistent on the continent.

Fiscal policy according to IMF (2014; 2015) is a primary and potent policy tool that impacts income distribution by affecting household welfare through monetary payment in the form of taxes and transfers and also through the provision of in-kind benefits such as spending on free education and health services. Similarly, Gupta (2018) argues that fiscal policy (taxation and spending) is the most powerful policy tool used by governments in advanced economies to achieve equitable income distribution in both the short and long term.

However, this policy tool has not been very effective in developing countries because they have lower tax-to-GDP ratios in the range of 15 – 20 percent while advanced countries have over 25 percent. Therefore, this limits the availability of funds for social spending on education and health. Fiscal redistribution is less effective in developing countries such as African countries because there is more reliance on indirect tax. Several empirical studies (see Salotti and Trecroci, 2018; Cevik and Correa-Caro, 2015; Muinelo-Gallo and Roca-Sagalés, 2013) are available on the redistributive effects of fiscal policies albeit primarily focused on advanced and emerging market economies. In this line of thought, Odusola (2017) argues that the central role of fiscal policy in addressing income inequality has long been acknowledged in the literature but there are few empirical studies in Africa to back this assertion. Few of these studies in Africa include Odusola, (2017) and Inchauste et al. (2015). But while Inchauste et al. (2015) focuses on South Africa, Odusola (2017) only provides a narrative without any econometric evidence.

Consequently, there is a need to delve into the distributional effects of fiscal policy in the African context. This study thoroughly examines the effects of fiscal policy in income redistribution in Africa by using variants of tax indicators as well as government expenditure indicators including spending on education at all levels. It should be noted however that, the empirical literature on income inequality in Africa so far has been skewed towards the proximate determinants of income inequality (Hundenborn et al., 2018; Adeleye et al., 2017; Anyanwu et al., 2016; Anyanwu, 2016; Dabla-Norris et al., 2015). Some of these determinants include trade openness, human capital, GDP per capita, globalization, government spending and resource rent. Other strands of literature (see Kunawotor et al., 2020; Chu and Hoang, 2020; Sulemana & Kpienbaareh, 2018; Berisha et al., 2018) tend to focus on institutions and governance with more particular attention towards corruption controls in addressing income inequality.

In addition to the distributional effects of fiscal policy, this study also focuses on the unintended distributional effects of monetary policy in Africa. This is because, even though fiscal policy is considered a primary tool in addressing income inequality and has more empirical evidence pointing towards that direction, recent trend of inequality studies are beginning to pay some attention to the potential distributional effects of monetary policy albeit so far focused on the advanced economies (see Mumtaz & Theophilopoulou, 2017; Coibion et al., 2017; Furceri et al., 2018; Davtyan, 2016; Villarreal, 2014). In particular, Furceri et al. (2018), Mumtaz and Theophilopoulou (2017) and Coibion et al. (2017) find that contractionary monetary policy increases income inequality in the USA and UK while Davtyan (2016) and Villarreal (2014) find a negative effect in US and Mexico respectively.

The foregoing arguments show that the effects of fiscal policy are clearly established in the extant literature while that of monetary policy seems complicated, and the complexity is due to various channels of impact (Aye, Clance and Gupta, 2018; Mumtaz and Theophilopoulou, 2017). The novelty and strength of this paper lie in the fact that it is one of the few in Africa to comprehensively study the redistributive roles of both fiscal and monetary policies using various indices. The rest of the paper reviews literature in section 2, methodology in section 3, results and discussion in section 4 and ends with summary and recommendations in section 5.

5.2 Literature Review

5.2.1 Fiscal Policy and Income Inequality

Fiscal policy is the primary tool used by governments to address income inequality. It uses the tools of taxation and expenditure to achieve three objectives according to IMF (2014). (1) To ensure macroeconomic stability. (2) To provide public goods and correct market failures. (3) To redistribute income. Tax and government spending policies can alter the distribution of income in the short and medium-term. An example is how spending on education can alter market inequality due to future earnings. The same applies to income tax and cash transfers that reduce the inequality of disposable income. IMF (2014) also argues that direct taxes are more redistributive than indirect taxes and social spending. Although a number of empirical studies have looked at the role fiscal policy plays in income redistribution, a chunk of those studies have their scope centered on the developed nations at the neglect of developing countries especially, Africa. An example is the recent study by Salotti and Trecroci (2018) which focused on 22 OECD economies over a 40-year period. The study evaluates the effects of fiscal policies on income inequality and poverty.

Fiscal policy is measured using six revenue series, three spending series and budget balance while income inequality is measured using disposable Gini coefficient or net Gini coefficient. The spending variables are general government final consumption expenditure, government spending on education and social security transfers. The revenue side variables are total tax, payroll tax, tax on social security, income tax, property tax, taxes on goods and services. The study includes controls such as public debt, the log of real GDP per capita, population growth, trade openness, secondary school enrollment, civil liberties, inflation and unemployment rate. The study finds fiscal flow variables to have a substantial distributive effect. More particularly, they find government spending, social spending, education spending, total tax, and income tax to have a negative relationship with income inequality. The study finds total tax and income tax to be significant and negatively associated with inequality. Also, they find population to be positively associated with income inequality while GDP per capita and trade openness are negatively associated.

The findings by Muinelo-Gallo and Roca-Sagalés (2013) is very similar to that of Salotti and Trecroci (2018) and also centered on 21 OECD countries. They find a negative and statistically significant effect of direct taxes on income inequality but an insignificant effect of indirect taxes. Focusing on Brazil, Russia, India and China (BRIC countries) and 30 other emerging market economies over the period 1980 - 2013, Cevik and Correa-Caro (2015) investigate the characteristics of income inequality but with a particular focus on the redistributive effect of fiscal policy. They find opposing effects of taxation and government spending on income inequality. Thus, while government spending worsens income distribution, taxation improves it in China while these effects appeared statistically insignificant for the other countries. The study measures income inequality using the net Gini coefficient while including real GDP per capita, tax revenue, government spending, trade openness, financial development, urbanization, human capital, and old age dependency as explanatory variables.

In Africa, Odusola (2017) study on fiscal space, poverty and inequality by specifically examining the role fiscal policies play in reducing inequality and poverty in Africa. The study finds that 29 out of 47 countries surveyed experienced declines in the distributional effects of fiscal policy measured by the difference between market and net Gini. Others, however, made good progress with the distributional impact of fiscal policy and this rose by 35 percent. The study mentions that there are four distinct groups of countries that emerge from the analysis of inequality and poverty. The most desirable group which are in North Africa have heavily invested in quality and accessible education and health services and so have lower inequality and poverty rates. The second group are countries in Southern Africa where poverty levels are relatively low but have high inequality indices. These countries such as South Africa have good social protection systems but have high racial divisions, skill deficits, and high unemployment rates. The third group of countries have high poverty amidst low inequality due to non-sophisticated economies. These countries include Niger, Burundi, Mali, Sao Tome and Principe, and Ethiopia. The fourth and final group have high inequality and poverty rates and include resource endowed nations such as Nigeria, the Republic of Congo, DRC, Angola, and Mozambique. The paper argues that these economies are plagued with the resource curse that is associated with the Dutch disease and rent-seeking behaviour. This study however failed to use any robust econometric approach in its analysis.

Furthermore, a study by Inchauste et al. (2015) on the impacts of fiscal policy on inequality in South Africa find that the burden of taxes such as personal income tax, value-added tax, excise taxes on alcohol and tobacco, and fuel levy is borne more by the rich while social spending also increases the income of the poor.

5.2.2 Monetary Policy and Income Inequality

Coibion, Gorodnichenko, Kueng and Silvia (2017) examine the effects of monetary policy shocks and their historical contribution to consumption and income inequality in the United States. Contractionary monetary policy is measured using the Federal Funds Rate (FFR) while inequality is measured with Gini coefficients using the Consumer Expenditure Survey (CEX) spanning the period 1969 - 2008. Their findings using impulse responses show that contractionary monetary policy increases inequality in total income, labor earnings, consumption and total expenditures. Their results also show that monetary policy shocks account for a non-trivial component of the historical cyclical variation in income and consumption inequality. They find that contractionary monetary policy tends to increase the income of those who receive financial income but decreases the income of business owners. Further, they show 5 channels by which monetary policy affects inequality. The first channel is the income composition channel which is due to the fact that there is heterogeneity in primary income sources among different households. While some depend on labour income, others rely on business income, financial, or transfer income.

Monetary policy does have a heterogeneous impact on these different income sources and may have redistributive effects. The second is the financial segmentation channel. This channel applies to agents who trade frequently in financial markets. Monetary policy tends to redistribute income in favour of these agents than others during expansionary monetary policy shocks. The third channel is the portfolio channel. Poor households who mostly tend to hold currency suffer more disproportionately from inflationary impact stemming from monetary policy than high-income households. The fourth channel is the savings redistribution channel which explains that an increase in interest rate will be of more benefit to savers than borrowers and savers are generally considered to be wealthier than borrowers. The final channel is the earnings heterogeneity channel. Monetary policy shocks affect high-income labour earnings and low-income labour earnings quite differently.

Very similar to the study by Coibion et al. (2017) is that of Davtyan (2016) who used multiple time series analyses to evaluate the distributional effects of monetary policy also in the USA. The specified model includes real GDP, prices, federal funds rate, and income inequality measured by Gini coefficient. The result from the impulse response function shows that contractionary monetary policy shock decreases income inequality significantly and this effect generally stays at that level for several years before it fades away. Thus, a long-run effect also exists. This finding is in contrast to the findings of Coibion et al. (2012; 2017) but the paper argues that this is due to the data source and income inequality measure used as Coibion's inequality measure did not consider the top one percent of the income distribution. The findings of Davtyan (2016) are similar to that of Villarreal (2014) who find that contractionary monetary policy reduce income inequality in Mexico. Particularly, the paper finds that unanticipated increases in the nominal interest rate reduces income inequality in the short run.

A recent paper by Furceri, Loungani and Zdzienicka (2018) provides new evidence of the effects of monetary policy shocks on income inequality for a panel of 32 advanced and emerging economies over the period 1990 to 2013. They use the short term policy rate as a proxy for monetary policy and the net Gini coefficient as a proxy for income inequality. Their findings also using the impulse response function show that on average, unexpected contractionary monetary policy shocks increase income inequality. However, predictable changes in the policy rate driven by improvement in economic fundamentals decrease inequality. This finding is robust after controlling for income inequality drivers such as trade openness, financial openness, financial depth and labour market regulation. The findings of Mumtaz and Theophilopoulou (2017) are similar to that of Coibion et al. (2017) and Furceri et al. (2018) as they find that contractionary monetary policy shocks lead to an increase in earnings, consumption and income inequality in the United Kingdom.

5.2.3 Determinants of Income Inequality

Generally, there is a vast amount of literature on the empirical determinants of income inequality. Few of these proximate income inequality drivers are discussed in this section. Chu and Hoang (2020) in a recent study examined the relationship between economic complexity and income inequality using a panel data of eighty-eight countries over the period 2002 - 2017. Their findings show that certain levels of education, trade openness, and government spending aid higher economic complexity in income redistribution. They also find that government spending, trade openness, and human capital have a statistically significant and negative impact on income inequality. Furthermore, they find an inverted U-shaped relationship between income inequality and GDP per capita and also between income inequality and institutions.

Quite similarly but centered on the global causes and consequences of income inequality in 100 advanced, emerging markets and developing countries, Dabla-Norris et al. (2015) find that several of inter-related factors can affect inequality and these factors may have differential effects depending on the country and income group. The following factors are identified to affect inequality; skill premium, financial globalization, labour market regulations, government spending, technology, financial deepening, and female mortality rate.

In Africa, Kunawotor, Bokpin and Barnor (2020) find that corruption control and the strict adherence to the rule of law significantly reduce income inequality. Their study focuses on the role that institutional quality plays amongst the empirical drivers of income inequality. The study includes 40 African countries and controlled for real GDP per capita, gross capital formation, dependency ratio, school enrollment rate, trade openness, political globalization, population growth, FDI, government expenditure, democracy, unemployment and natural resource rent. Similarly, Adeleye, Osabuohien and Bowale (2017) examine the role institutions play in the finance-inequality nexus in 42 Sub-Saharan African countries between the periods 1996 - 2015. Their findings show that financial development does not only positively impact income distribution but this impact does improve in the presence of a strong institutional framework. The study includes age-dependency ratio, GDP growth rate and inflation as controls. Furthermore, Anyanwu (2016) writing on the main drivers of inequality in Southern Africa finds real GDP per capita, gross capital formation, population growth, the square of political globalization and the first lag of income inequality to positively and significantly influence inequality. On the other hand, he find natural resource rent, the square of real GDP per capita, secondary school enrolment, political globalization and the second lag of inequality to negatively affect income inequality.

Similarly, Anyanwu et al. (2016) find the following as the main drivers of income inequality in West Africa; the first two lags of inequality, secondary school enrolment, GDP per capita, square of GDP per capita, population density, gross capital formation, government expenditure, resource rent FDI inflows, trade openness, personal remittances received, political globalization and its squared term, social globalization, democracy, civil war, unemployment rate. Some of these key income inequality drivers informed our choice of control variables.

5.2.4 Summary of gaps in the literature

The empirical studies on fiscal policy and income inequality discussed in the literature largely address concerns regarding OECD countries and emerging markets economies. Most of these studies neglected developing countries in Africa. The few available studies on Africa are either exploratory without providing econometric evidence or centered on individual countries in Africa. This present study fills this gap by considering 52 countries in Africa for which data is available for. Also, this study conducts analysis using econometric approaches and also uses different variants of fiscal policy in addition to fiscal redistribution. Similarly, although the literature on the linkage between monetary policy and inequality is nascent, the few available studies focused on the advanced economies like the USA and UK and emerging market economies while this study focuses on African economies.

5.3 Methodology

5.3.1 Model specification, definition & measurement of variables and a priori expectations

The baseline specification of this study's empirical model takes root from the large strand of literature on the determinants of income inequality (see Salotti and Trecroci, 2018; Anyanwu, 2016; Cevik and Correa, 2015). Also, this paper follows recent studies (see Kunawotor et al., 2020; Adeleye et al., 2017; Anyanwu, 2016; Anyanwu et al., 2016) that use similar specifications of income inequality in their empirical modeling and identify income inequality to be persistent. This paper's empirical models therefore, have income inequality to be predicted by the first period lag of income inequality, fiscal and monetary policy as the explanatory variables, and a vector of controls shown below;

$$IncInequality_{i,t} = \alpha_1 IncInequality_{i,t-1} + \alpha_2 FiscalPolicy_{i,t} + \beta' X_{i,t} + \mu_i + \mu_t + \varepsilon_{i,t} \quad \ldots\ldots (1)$$

$$IncInequality_{i,t} = \sigma_1 IncInequality_{i,t-1} + \sigma_2 MonetaryPolicy_{i,t} + \beta' X_{i,t} + \eta_i + \omega_t + \lambda_{i,t} \quad \ldots. (2)$$

Income inequality ($IncInequality_{it}$) is the outcome variable and it is measured using the net/disposable Gini index. The net/disposable Gini index estimates inequality using equivalized household disposable (post-tax, post-transfer) income. The index varies from 0 to 100 where 0 indicates perfect equality while 100 indicates perfect inequality. The within-country Gini coefficient measures the distribution of income or consumption among households or individuals in a country. The subscripts 'i' and 't' represent a given country and a given year respectively. $IncInequality_{i,t-1}$ represents the first lag of income inequality in a given country. It is expected that the immediate past level of income inequality will drag the present income inequality from reducing and hence exhibiting a great degree of inertia.

The distinguishing feature between equation 1 and equation 2 is the explanatory variables. The explanatory variables are variants of fiscal policy variables ($FiscalPolicy_{it}$) shown in equation 1 and monetary policy variables ($MonetaryPolicy_{it}$) shown in equation 2. Fiscal policy is proxied by using fiscal redistribution, tax indicators as well as general government expenditure indicators. Fiscal redistribution is defined as the difference between the market Gini coefficient (pre-tax, pre-transfer Gini) and disposable Gini coefficient (post-tax, post-transfer Gini). The tax indicators are total tax revenue, total direct tax, total indirect tax, and property tax. The total direct tax include taxes on income, profits and capital gains. The total indirect taxes include taxes on goods and services, taxes on international trade and other taxes. A negative relationship between fiscal distribution and income inequality implies an improvement in fiscal redistribution while a positive relationship implies an erosion in fiscal redistribution. It is also the paper's expectation that direct taxes will be progressive and indirect taxes will be regressive.

The general government expenditure indicators are general government final consumption expenditure (% of GDP), total general government expenditure on education (% of GDP), expenditure on primary education (% of government expenditure on education), expenditure on secondary education (% of government expenditure on education) and expenditure on tertiary education (% of government expenditure on education). The general government final consumption expenditure comprises all government current expenditures for purchases of goods and services including compensation of employees and expenditures on national defense and security. The paper expects that general government expenditure and spending on public good provision will trickle down to the poor households through job creation and social interventions hence, a negative relationship with income inequality. It is also expected that spending on primary and secondary education will reduce income inequality while spending on tertiary education will further widen the income inequality gap. Monetary policy is measured using the monetary policy interest rates. However, due to limited data for monetary policy interest rates, the paper introduces lending interest rates and deposit interest rates as alternative proxies for monetary policy. The nexus between the interest rates and income inequality is a priori indeterminate as indicated in literature.

The control variables are represented by the vector “X_{it}”. These set of controls include real GDP per capita and its squared term, political globalization and, democracy, trade openness, foreign direct investment, age dependency ratio, population growth rate, school enrollment rate, unemployment rate, gross capital formation and natural resource rent.

Real Gross Domestic Product (GDP) per capita is measured by taking the natural log of constant GDP per capita. Also, we introduce the squared of real GDP per capita. It is expected that real

GDP per capita will increase income inequality in the short term and decrease it in the long term in line with Kuznets' hypothesis.

School enrollment is measured by the gross secondary school enrollment rate which is the most frequently used measure of human capital (see Kunawotor et al. 2020; Salotti & Trecroci, 2018; Anyanwu, 2016). As a measure of skills diffusion and human capital development, it is expected that a higher enrollment rate will decrease income inequality in Africa all things being equal. It is also expected that a positive relationship will exist between population growth rate, unemployment rate and income inequality.

Trade openness is measured as the sum of total export and total imports scaled by GDP. The relationship between trade openness and income inequality is mixed, as posited by Dabla-Norris et al. (2015). A negative relationship could mean that trade liberalization opens more opportunities for employment of low skilled and low-income earners in a country where there are many low-skilled workers. A positive relationship means that the highly skilled and affluent get better opportunities in exporting firms based on the assumption that technological change is high-skilled biased. Foreign Direct Investment (FDI) is measured as the net inflow of foreign direct investments as a ratio of GDP. The paper expects a negative relationship with income inequality.

Natural resource rents depict the extent to which a country relies on natural resources for development and it is measured by resource rents to GDP. It is the expectation that these resources will reduce income inequality when applied well, all things being equal. Similarly, gross capital formation as a percentage of GDP proxies the usage of physical capital in production. This is expected to generate more jobs and higher earnings and hence the potential to reduce income inequality.

Age dependency ratio is the sum of the proportion of the young age population (0 -15 years) and the old age population (65 years and above) to the working-age population (16 – 64 years). It is expected that a higher dependency ratio will translate to lower-income per capita and hence a higher income inequality.

Political globalization is measured by KOF's index and comprises the absolute number of embassies in a country, personnel contributed to UN Security Council missions (% of the population), number of internationally oriented non-governmental organisations (NGOs) operating in a country, number of international inter-governmental organisation in which a country is a member, international treaties signed and number of distinct treaty partners of a country with bilateral investment treaties. The paper expects that political globalization will reduce inequality. Finally, democracy is proxied by the polity2 index and it ranges from -10 to 10 with higher values indicating a high level of democracy in a country while lower values indicate autocracy. It is expected that democracy will reduce inequality as there is a guaranteed fair share of the national cake. Finally, u_i and η_i represent the country fixed effects while ω_t and u_t represent the time fixed effects. $\varepsilon_{i,t}$ and $\lambda_{i,t}$ represent the idiosyncratic error term respectively.

5.3.2 Sources of data and Scope of the study

The study employs panel data over the period 1990 – 2017 and this includes 52 African countries (see Appendix 1). The data on income inequality is sourced from the Standardized World Income Inequality Database (SWIID)) at the United Nations University World Institute for Development Economics Research (UNU-WIDER). Data from SWIID is more preferable as it collates data with comparable figures across various countries over a relatively long period. Data on tax revenue is sourced from the International Centre for Tax and Development (ICTD) and UNU-WIDER government revenue dataset. Data on political globalization is gleaned from the

KOF 2019 index of globalization while that of democracy (polity 2) is taken from Marshall's Polity IV Project. Monetary policy interest rate is taken from the International Monetary Fund (IMF). The other variables including all government expenditure variables, lending interest rate, deposit interest rate, real GDP per capita, trade openness, foreign direct investment, age dependency ratio, population growth rate, school enrollment, unemployment, gross capital formation and natural resource rent are all taken from World Banks World Development Indicators (WDI).

5.3.3. Estimation Technique

The study deploys the two-step system Generalized Method of Moments (GMM) estimation approach with robust standard errors as well as the simultaneous quantile regression technique. Also, Panel Cointegration test and Panel Vector Autoregressive Models (VAR) are used. The choice of the dynamic GMM approach is justified by five reasons following recent GMM centered literature (Kunawotor et al., 2020; Asongu et al., 2019; Tchamyou et al., 2019; Agoba et al., 2019; Fosu & Abass 2019). First, the cross-sectional units which are the number of countries are higher than the time series (T) which represents the years. Thus, the countries are 52 while the sampled period is 28 years. Secondly, the dataset is a panel data and the estimation strategy accounts for cross-country differences in the process of estimation. Thirdly, GMM has the ability to address inherent endogeneity issues in two ways; GMM controls for unobserved heterogeneity by accounting for time-invariant omitted variables. Also, GMM identifies instrumental variables which are correlated with the endogenous independent variable but not the dependent variable to correct for simultaneity bias or reverse causality.

Reverse causality may be a concern in this study since fiscal policy can also affect income inequality. Thus, the desire of the authorities to mitigate inequality may trigger tax and spending decisions (Salotti and Trecroci, 2018). Fourth, income inequality shows a great degree of persistence and so it depends on its lag(s) (see Asongu et al., 2020; Kunawotor et al., 2020; Salotti and Trecroci, 2018; Shimeles and Nabassaga, 2018; Adeleye et al. 2017; Anyanwu et al., 2016; Cevik and Correa, 2015). The persistent nature of income inequality requires a dynamic empirical modelling and the need to use a dynamic estimation technique such as GMM. Finally, due to the general difficulties in identifying an external instrument, GMM is preferred.

All the necessary diagnosis tests to confirm the robustness of GMM are present. The Hansen test, tests for the validity of the moment conditions. Also, the test of no second-order serial correlation is performed by the Arellano–Bond test for autocorrelation (AR (2)). All these diagnostic tests proved satisfactory. The bootstrap simultaneous quantile regression estimation technique is used to check for robustness of some of the results. The quantile regression detects and controls for outliers. Its usage is consistent with recent development literature in economics (see Altunbas &Thornton, 2019; Asongu & Nwachukwu, 2016; Asongu, 2014).

5.4. Empirical Results

5.4.1 Descriptive statistics and Correlation matrix

The mean score of income inequality measured by net Gini or disposable income Gini coefficient in Africa is 43.34 while the corresponding market income Gini coefficient is 48.25 and this is shown in Table 5.1. This means that income taxes and transfers are responsible for reducing the market Gini coefficient by 4.91 points. Gupta (2018) and IMF (2015) find that income taxes and transfers are responsible for a reduction in market Gini coefficients in some selected advanced economies and Latin American economies by 17 and 4 points respectively. This explains that the redistributive impact of taxes and transfers in Africa and Latin America has not been so effective relative to the advanced economies probably due to the higher composition and greater reliance on indirect taxes in the tax structure.

Regionally, Southern Africa has the highest mean net Gini of 53.23. This is followed by East Africa (41.24), West Africa (41.05) and North Africa (37.83). This result is in line with the findings of Kunawotor et al., (2020); Adeleye et al., (2017) and Odusola (2017). Odusola (2017) particularly mentions that Northern African countries such as Egypt, Morocco, Mauritius and Tunisia have low Gini coefficients because of massive investments in quality education and affordable health services. The tax effort in Africa also appears low with an average of 15.96 percent. This implies that there is more space for revenue-generating capacity in Africa. As expected, indirect tax (8.895%) dominates direct tax (6.166%) in Africa. The property tax collection rate in Africa is almost negligible (0.139%). African governments also appear to spend more on primary and secondary education than on tertiary education. There is no general concern for multicollinearity as reflected in the correlation matrix and the variance inflation factors with none greater than 10. The result of the Variance Inflation Factors (VIFs) is shown in Table 5.3.

Table 5. 1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Net Gini	986	43.344	7.099	30.2	62.4
Market Gini	986	48.254	7.921	33.7	70.7
Total tax (% of GDP)	565	15.958	8.532	.573	55.698
Direct tax (% of GDP)	578	6.166	4.005	.199	18.846
Indirect tax (% of GDP)	639	8.895	6.142	0	45.834
Property tax (% of GDP)	556	.139	.276	0	1.469
Government expenditure (GDP)	1263	15.302	7.497	.911	73.577
Expenditure on education (GDP)	658	4.265	2.591	1.012	44.334
Expend on primary education	448	44.062	11.352	17.574	98.668
Expend on secondary education	443	30.185	10.182	0	71.587
Expend on tertiary education	478	19.534	9.093	0	59.02
Monetary policy rate	312	10.881	11.154	2	70
Lending rate	875	18.291	12.671	4.737	97.336
GDP per capita	1390	2211.006	2926.692	164.337	20512.941
Political globalisation	1453	53.602	17.936	8.21	92.148
Democracy – Polity2	1345	.616	5.658	-10	10
Trade openness	1251	.693	.35	.191	3.762
FDI	1388	4.036	9.132	-8.589	161.824
Age dependency ratio	1450	84.509	15.633	41.293	112.849
Population growth	1450	2.379	1.085	-6.766	8.118
Secondary school enrollment rate	862	41.225	25.644	5.221	115.957
Unemployment rate	1377	9.299	7.593	.285	37.94
Gross capital formation	1293	21.575	9.888	-2.424	85.101
Natural resource rent	1423	12.263	12.336	0	84.24

Table 5. 2: Correlation matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1) Net gini	1.000														
(2) Tax	0.320	1.000													
(3) Gov't expenditure	0.309	0.538	1.000												
(4) Lending rate	0.020	-0.146	-0.132	1.000											
(5) GDP per capita	0.190	0.207	0.207	-0.096	1.000										
(6) Political glob	-0.201	-0.071	-0.209	-0.007	-0.070	1.000									
(7) Polity2	0.248	0.253	0.044	-0.087	-0.009	0.105	1.000								
(8) Trade openness	0.115	0.166	0.266	0.040	0.357	-0.086	0.101	1.000							
(9) FDI	-0.052	0.160	0.085	0.000	0.040	-0.132	0.019	0.300	1.000						
(10) Age dependency	-0.065	-0.471	-0.253	0.072	-0.627	-0.229	-0.148	-0.356	-0.033	1.000					
(11) Population growth	-0.166	-0.534	-0.228	-0.054	-0.172	-0.007	-0.032	-0.202	0.094	0.450	1.000				
(12) School enrollment	0.193	0.411	0.216	-0.268	0.687	0.215	0.245	0.291	0.024	-0.812	-0.501	1.000			
(13) Unemployment	0.466	0.552	0.310	-0.033	0.458	-0.066	0.010	0.362	0.013	-0.435	-0.327	0.451	1.000		
(14) Gross capital	0.004	0.252	0.200	-0.131	0.273	0.139	0.084	0.343	0.292	-0.276	-0.006	0.176	0.141	1.000	
(15) Resource rent	-0.308	-0.461	-0.153	0.064	0.169	0.019	-0.216	0.168	0.219	0.098	0.269	-0.208	-0.026	0.076	1.000

Table 5. 3: Variance Inflation Factor

	VIF	1/VIF
Real GDP per capita	6.188	.162
School enrollment rate	5.256	.19
Tax	4.163	.24
Population growth	4.121	.243
Unemployment	3.701	.27
Trade openness	3.297	.303
Age dependency	2.823	.354
Government expenditure	2.695	.371
Political globalization	2.478	.404
Polity 2	2.316	.432
Gross capital formation	2.15	.465
FDI	2.114	.473
Natural resource rent	1.8	.556
Lending rate	1.419	.705
Mean VIF	3.18	

5.4.2 Empirical results of the Effects of Fiscal Policy on Income Inequality

The results of the redistributive effects of fiscal policy comprise the tax dimension, the expenditure dimension, and fiscal redistribution (the difference between gross Gini and net Gini). The results of the tax variants as well as fiscal redistribution are presented in Model 1 – Model 5 in Table 5.4 while that of the expenditure side is presented in Model 11 – Model 15 in Table 5.6. The result in Model 1 shows the effectiveness of fiscal policy in income redistribution as reflected in the negative nexus between income inequality and 'fiscal redistribution'. Income inequality is reduced by 2.3 percent implying that income taxes and transfers play a significant role in income redistribution in Africa.

A similar assertion is made by Odusola (2017) who avers that the composition of taxes and quality spending are yielding fruits in reducing income inequality in Africa. More particularly, our findings indicate that total tax revenue has a negative effect on income inequality shown in Model 2. Total tax thus reduces income inequality by 3.2 percent and this implies that total tax revenue has the potential to narrow the economic gap between the haves and have-nots. Salotti and Trecroci (2018) had similar findings for OECD countries. Further and more interestingly, the findings reveal that direct tax has a negative and statistically significant effect on income inequality as shown in Model 3. The income inequality-reducing effect of direct tax which comprise tax on income, profit and capital gains is 4. 3 percent. This appears to be more progressive than other form of taxes and hence direct tax has the potency to effectively redistribute income in favour of the less privileged.

Salotti and Trecroci (2018) also find a negative nexus between income tax and economic inequality. The paper also finds that indirect tax has a positive effect on income inequality and this can be seen in Model 4 but appears statistically insignificant. Thus, taxes on goods and services and taxes on international trade have no statistically significant effect on income inequality in the sample. Earlier findings of Muinelo-Gallo and Roca-Sagalés (2013) are quite similar to this as they find a significant negative effect of direct taxes on income inequality in OECD countries and an insignificant effect of indirect taxes on income inequality. Efforts by governments to increase the share of direct tax to the total tax net will greatly improve income redistribution in Africa. This is because the current tax structure in Africa appears quite regressive as a higher percentage comes from indirect tax (8.895) than direct tax (6.166). African countries may need to put more premium on broadening the tax net on incomes (payroll tax and corporate tax) as well as capital gains tax rather than increasing the tax rates. This can be achieved by taking measures to bring in more citizens and corporate entities. These policy measures will ensure that a fair tradeoff is struck between equality and efficiency since a higher marginal tax rate on income may discourage individuals who earn high income from exerting more efforts.

Lastly, but concerning the tax side, the study finds property tax to be positively associated with income inequality by 2.7 percent and statistically significant as well in Model 5. Thus, levying property tax has income un-equalizing and regressive impact in Africa. This may be due to the insignificant proportion of people who fall within this tax bracket. Also, property prices keep soaring in most African countries and property owners make significant windfalls but pay insignificant amounts in property taxes. It may also be because property owners charge high rent but pay paltry amounts in taxes and some of these taxes may eventually be borne by the poor tenant further widening the inequality gap. Gupta (2018) asserts that property taxes have less progressivity in developing economies due to weak compliance levels as well as a narrow tax base. Because it was expected that property tax would rather cause a decrease in income inequality as it is considered a form of direct tax, the study used the simultaneous quantile regression for robustness checks. The results presented in Table 5.5 show that property tax in a similar fashion increases income inequality at the lower and mid quantiles of the income inequality distribution. Thus, property tax appear statistically significant with a positive sign at the 10th, 25th and 50th percent quantiles in Model 6, Model 7 & Model 8 respectively. The 75th and 90th percent quantiles appear statistically insignificant in Model 9 & Model 10.

The second part of the distributional impact of fiscal policy focuses on the government expenditure side. First, the paper finds no statistically significant effect of general government final consumption expenditure on income inequality as depicted in Model 11. This implies that untargeted general government spending has no statistically significant redistributive effect. Kunawotor et al. (2020) however, find that final government expenditure widens the income inequality gap. Similarly, the paper finds no statistically significant impact of total general government expenditure on education in Model 12.

However and more intriguingly, the findings in Model 13 reveal that general government spending on primary education is statistically significant with a negative sign. Thus, spending on primary education reduces income inequality by about 0.70 percent. This implies that government expenditure on primary education which includes both current expenditure and capital expenditure plays a major role in redistributing income in favour of the less resourceful. This implies that granting more access to children of the less privilege to acquire basic education has an income-equalizing effect. This argument appears plausible since lower income groups are the main patronizers of government basic schools in Africa. Also, the findings show that government expenditure on secondary education rather promotes unequal distribution of income in Model 14 by about 1.3 percent. A similar result holds for government expenditure on tertiary education as it appears to increase income inequality by about 1 percent as depicted in Model 15. The possible explanation to this finding is that, secondary education and tertiary education narrows down to specialized courses and skill acquisition which comes with higher income rewards hence further widening the income inequality gap. For example, while all students take same courses at the basic level, students who progress to secondary schools are trained in business or science related courses. Those who progress further specialize in accounting or engineering programs and the income levels of these professions are above the average incomes. These results corroborate the assertion by Gupta (2018) and IMF (2014) that basic and primary education spending is more progressive while spending on secondary and tertiary education is regressive. Gupta (2018) also argues that non-cash spending to expand basic education and health services is more likely to ensure equitable income distribution. Intuitively, government spending on primary education has a significant equalizing effect as the income inequality gap appears bridged when the government spends more on primary education. This is probably because a much larger chunk of total educational spending (44 percent) goes to primary education shown in Table 5.1 and the redistributive effects of lower education trickle down more easily due to its wider coverage. Thus, a larger proportion of people are empowered through human capital development and hence are more likely to secure employment and this helps narrow the income inequality gap.

The first period lag of income inequality appears statistically significant with high coefficients in all models and this is consistent with the essence of the usage of the dynamic GMM model. Also, persistency is confirmed in our study as the data shows evidence of correlation (0.9993) between our outcome variable in levels and its first-period lag and this exceeds the threshold (0.8) needed to establish persistence in literature This implies the persistent nature of income inequality as higher income inequality levels in the past may cause a slow change in the current levels. This is similar to the findings of Chu and Hoang (2020); Kunawotor et al. (2020); Salotti and Trecroci (2018) and Adeleye et al. (2017).

The result in Model 5 supports the Kuznets hypothesis of an inverted U-shape effect between economic development and income inequality. Thus, income distribution in African countries may become more even with higher economic development and the threshold or point of inflection for real GDP per capita occurs at US$1924.44. This can be observed in Model 5 as real GDP per capita has a positive sign while its square term has a negative sign and they both appear statistically significant. The existence of the Kuznets curve in Africa confirms the results of Anyanwu et al. (2016) and Anyanwu (2016) in West and Southern Africa respectively and Cevik and Correa-Caro (2015) in China.

School enrollment as a measure of skill premium and human capital development has a negative and statistically significant effect on income inequality in Model 14. This means that the diffusion of human capital among the populace in Africa may empower households economically and this may help reduce the income inequality gap. That is, as more people become enlightened through the educational systems, their skill set is enhanced and a greater propensity to acquire a job or reduce the earnings gap between the skilled and unskilled. This result is in line with the findings of Kunawotor et al. (2020) for Africa, Anyanwu (2016) for Southern African countries, Anyanwu et al (2016) for West Africa, and Dincer and Gunalp (2012) for the United States.

The study finds natural resource rent to be statistically significant with a negative effect on income inequality in Model 2. African countries can leverage the abundance and dependence on natural resources to help poor households catch up on the income and wealth ladder lending support to the findings of Kunawotor et al. (2020), Anyanwu (2016) but contradicts that of Anyanwu et al (2016).

Similarly, the paper finds gross capital formation which proxies for domestic capital investment to have a negative and significant effect on income inequality in Africa in almost all the models except Model 2 & Model 4. This confirms the findings of Kunawotor et al. (2020) in Africa and Lee et al. (2013) in Korea but contradicts that of Anyanwu (2016) and Anyanwu et al (2016) in South Africa and West Africa respectively. This finding is in line with the a priori expectations and the implication is that, as more domestic investments are made, it creates more employment and earnings opportunities for the less privileged hence reducing the income inequality gap.

Age dependency ratio and unemployment contrary to the study's expectation rather appears to reduce income inequality while trade openness increases income inequality as shown in Model 13 & 14. Thus, trade liberalization favours the rich than the poor probably due to the high-skill levels required for those new jobs in the exporting sector. Population growth has a positive relationship with income inequality in most of the models including Model 3 - Model 5. As more and more people are made to share the limited available resources, the per capita distribution reduces, and due to unfair distribution, the economic gap may further widen. This conforms to the result of Salotti and Trecroci (2018) who find larger countries to have higher Gini indices.

Finally, among the set of controls, democracy has a negative and statistically significant effect on income inequality in Model 1 & Model 12. Countries that tend to practice democracy may see their inequality gap narrowing than those that lean towards autocracy probably because of fairness in the distribution of the national cake. All the other variables including real GDP per capita and its square, political globalization, and foreign direct investment inflows remain statistically insignificant.

It is worth mentioning that using Panel Cointegration test and Panel Vector Autoregressive Model (VAR), there is sufficient evidence based on the results of the Wald test that taxes does granger cause income inequality. However, a reverse causality does not exist. These results are shown in Appendix 3.

Table 5. 4: The Effects of Fiscal distribution and Taxes on Income Inequality

VARIABLES	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
Lag of income inequality	1.035***	1.039***	1.058***	1.067***	1.003***
	(0.017)	(0.024)	(0.021)	(0.036)	(0.019)
Fiscal redistribution	-0.024*	--	--	--	--
	(0.014)				
Total tax	--	-0.032**	--	--	--
		(0.013)			
Direct tax	--	--	-0.043**	--	--
			(0.021)		
Indirect tax	--	--	--	0.013	--
				(0.020)	
Property tax	--	--	--	--	0.270**
					(0.126)
Real GDP per capita	0.617	0.266	0.051	0.717	0.912*
	(0.560)	(1.346)	(1.109)	(1.717)	(0.514)
Real GDP per capita^2	-0.041	-0.030	-0.006	-0.046	-0.060*
	(0.039)	(0.099)	(0.080)	(0.129)	(0.034)
Political globalisation	0.002	0.005	0.008	0.005	-0.005
	(0.003)	(0.004)	(0.005)	(0.008)	(0.005)
Democracy - polity2	-0.005*	-0.006	-0.008	-0.002	-0.005
	(0.003)	(0.006)	(0.005)	(0.009)	(0.005)
Trade openness	-0.005*	0.274	0.367	0.425	0.145
	(0.002)	(0.317)	(0.265)	(0.427)	(0.225)
FDI	0.002	0.000	0.001	0.002	0.004
	(0.003)	(0.005)	(0.005)	(0.011)	(0.005)
Age dependency ratio	-0.006	-0.020**	-0.018***	-0.016**	-0.004
	(0.005)	(0.007)	(0.005)	(0.008)	(0.003)
Population growth	-0.006	0.089	0.119**	0.124**	0.099***
	(0.047)	(0.064)	(0.044)	(0.053)	(0.019)
School enrollment	-0.002	-0.003	-0.004	-0.007	0.001
	(0.001)	(0.003)	(0.003)	(0.005)	(0.002)
Unemployment	-0.018**	-0.005	-0.024**	-0.046	-0.009
	(0.007)	(0.013)	(0.011)	(0.032)	(0.012)
Gross capital formation	-0.006*	-0.004	-0.007*	-0.010	-0.015***
	(0.003)	(0.004)	(0.004)	(0.007)	(0.003)
Natural resource rent	0.003	-0.007**	-0.002	-0.002	-0.003
	(0.004)	(0.003)	(0.004)	(0.007)	(0.003)
Constant	-2.889	-0.326	-1.412	-4.384	-2.880
	(2.277)	(4.873)	(3.053)	(4.270)	(2.443)
Observations	472	260	267	273	254
Number of countries	40	23	24	25	24

Number of instruments	18	21	21	21	16
Wald test (Prob > F)	0.000	0.000	0.000	0.000	0.000
AR(1):(Pr > z)	-1.94(0.052)	-2.13(0.033)	-2.20(0.028)	-2.41(0.016)	-3.09(0.002)
AR(2):(Pr > z)	-0.89(0.376)	-0.56(0.576)	0.64(0.523)	0.80(0.422)	-0.55(0.580)
Sargan: (Prob > chi2)	0.78(0.854)	1.10(0.982)	0.93(0.988)	3.56(0.735)	0.48(0.487)
Hansen: (Prob > chi2)	1.76(0.623)	3.32(0.768)	2.86(0.826)	3.75(0.710)	0.24(0.621)

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 Model 1 addresses the role of fiscal redistribution. Model 2 concerns the effects of total taxes on income inequality. Model 3, 4, 5 discuss the effects of direct tax, indirect tax and property taxes on income inequality respectively.

Table 5. 5: The Effects of Property Tax on Income Inequality – Quantile Regression

VARIABLES	MODEL 6 0.10	MODEL 7 0.25	MODEL 8 0.50	MODEL 9 0.75	MODEL 10 0.90
Property Tax	**4.563***** (1.477)	**5.046***** (1.512)	**6.509***** (1.836)	**5.370** (3.312)	**-0.778** (2.562)
Real GDP per capita	22.09*** (5.434)	21.73** (8.797)	30.59*** (8.649)	15.81 (12.57)	-19.50 (16.98)
Real GDP per capita^2	-1.562*** (0.370)	-1.578*** (0.592)	-2.131*** (0.567)	-1.115 (0.935)	1.382 (1.207)
Political globalisation	-0.138*** (0.047)	-0.204*** (0.038)	-0.232*** (0.038)	-0.210*** (0.053)	-0.161*** (0.057)
Democracy - polity2	-0.169*** (0.063)	-0.088 (0.072)	-0.047 (0.046)	-0.011 (0.079)	-0.247** (0.098)
Trade openness	-0.551 (2.151)	-4.599 (2.910)	-7.868*** (1.904)	-8.785*** (1.925)	-3.906 (2.485)
FDI	0.089 (0.084)	0.019 (0.069)	0.117 (0.095)	0.068 (0.092)	0.012 (0.079)
Age dependency ratio	0.230*** (0.076)	0.251*** (0.061)	0.150** (0.072)	0.108 (0.101)	-0.213** (0.091)
Population growth	-1.531** (0.760)	-1.172 (0.800)	0.176 (0.669)	-0.248 (1.375)	2.424** (1.208)
School enrollment	0.148*** (0.049)	0.184*** (0.029)	0.142*** (0.032)	0.107*** (0.033)	0.005 (0.029)
Unemployment	0.204 (0.143)	0.451*** (0.142)	0.538*** (0.070)	0.684*** (0.099)	0.604*** (0.144)
Gross capital formation	-0.133** (0.057)	-0.095* (0.049)	-0.178*** (0.063)	-0.152*** (0.040)	-0.057 (0.063)
Natural resource rent	-0.033 (0.046)	-0.048 (0.038)	-0.054 (0.053)	-0.006 (0.089)	-0.111 (0.102)
Constant	-48.75** (21.23)	-43.71 (33.96)	-64.13** (30.14)	-6.141 (39.23)	137.2** (57.61)

Observations	256	256	256	256	256
Pseudo R^2	0.333	0.364	0.438	0.560	0.647

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

Table 5. 6: The Effects of Government Expenditure on Income Inequality

VARIABLES	MODEL 11	MODEL 12	MODEL 13	MODEL 14	MODEL 15
Lag of income inequality	1.007***	1.016***	1.013***	1.106***	1.035***
	(0.012)	(0.013)	(0.011)	(0.030)	(0.019)
Gov't Expenditure	0.003	--	--	--	--
	(0.006)				
Expenditure on education	--	0.017	--	--	--
		(0.016)			
Expenditure - primary edu	--	--	-0.007**	--	--
			(0.003)		
Expenditure - secondary edu	--	--	--	0.013*	--
				(0.007)	
Expenditure - tertiary edu	--	--	--	--	0.010**
					(0.005)
Real GDP per capita	0.003	0.024	-0.014	0.162	-0.298
	(0.440)	(0.584)	(0.440)	(1.336)	(0.863)
Real GDP per capita^2	0.001	0.003	0.002	-0.016	0.027
	(0.029)	(0.039)	(0.029)	(0.095)	(0.061)
Political globalization	-0.002	0.001	0.001	0.009	0.003
	(0.002)	(0.003)	(0.002)	(0.006)	(0.003)
Democracy - polity2	-0.004	-0.008*	-0.002	0.001	-0.001
	(0.003)	(0.004)	(0.004)	(0.009)	(0.005)
Trade openness	-0.022	0.223	0.242*	0.806**	0.261
	(0.101)	(0.134)	(0.121)	(0.362)	(0.190)
FDI	0.005	0.006	0.005	0.004	0.001
	(0.003)	(0.005)	(0.007)	(0.006)	(0.006)
Age dependency ratio	-0.001	-0.006*	-0.006	-0.022**	-0.005
	(0.003)	(0.004)	(0.004)	(0.009)	(0.004)
Population growth	-0.025	0.145***	0.157**	0.101	0.145**
	(0.017)	(0.042)	(0.059)	(0.076)	(0.061)
School enrollment	-0.000	-0.001	-0.001	-0.014**	-0.001
	(0.002)	(0.003)	(0.003)	(0.006)	(0.003)
Unemployment	-0.008	-0.014*	-0.008	-0.060**	-0.027*
	(0.005)	(0.008)	(0.010)	(0.024)	(0.016)
Gross capital formation	-0.006**	-0.006**	-0.008**	-0.009*	-0.006**
	(0.003)	(0.003)	(0.003)	(0.005)	(0.003)

Natural resource rent	-0.003	-0.006	-0.006	-0.002	-0.002
	(0.003)	(0.004)	(0.004)	(0.005)	(0.004)
Constant	0.008	-0.742	-0.052	-3.635	-0.856
	(1.583)	(2.015)	(1.594)	(4.674)	(3.214)
Observations	469	268	196	196	215
Number of countries	40	37	32	32	34
Number of instruments	21	21	21	21	21
Wald test (Prob > F)	0.000	0.000	0.000	0.000	0.000
AR(1):(Pr > z)	-2.06(0.039)	-2.89(0.004)	-1.85(0.065)	-0.76(0.447)	-1.66(0.096)
AR(2):(Pr > z)	-0.96(0.337)	0.90(0.370)	0.25(0.803)	0.71(0.477)	1.11(0.265)
Sargan test:(Prob > chi2)	2.13(0.908)	5.79(0.447)	2.67(0.849)	2.29(0.892)	9.90(0.129)
Hansen test: (Prob > chi2)	2.00(0.919)	3.71(0.716)	2.47(0.872)	1.46(0.962)	7.01(0.320)

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 Model 11 discusses the effects of government spending on income inequality. Model 12 discusses the effects of total educational spending on income inequality. Model 13, 14 & 15 address the relationship between government spending on primary, secondary & tertiary education and income inequality respectively.

5.4.3 Empirical results of the Effects of Monetary Policy on Income Inequality

This section addresses the role monetary policy plays in income redistribution. The findings show that increases in the monetary policy interest rate causes a reduction in income inequality albeit statistically insignificant and this is shown in Model 16. Given that the available data on monetary policy interest rate is very limited reducing the sample of countries to only 17, the study used lending interest rates and deposit interest rates as alternative proxies for monetary policy.

The paper finds that contractionary monetary policy (increase in the lending interest rate) reduces income inequality in Model 17 and it is statistically significant. This is probably because contractionary monetary policy lowers the incomes of business owners as a lot more is required in debt servicing hence narrowing the income gap. This is also because richer households according to Coibion et al. (2017) receive relatively more business income. Also, a rise in the lending interest rate may have a detrimental consequence on the incomes of variable interest mortgage payers who usually form part of the richer households. This result corroborates the findings of Davtyan (2016) who also find that contractionary monetary policy reduces income inequality in the USA in both the short run and long run. The findings in Model 18 also show that increases in the deposit rate raises the financial income of depositors or surplus fund holders and may increase income inequality. This is however not statistically significant. Coibion et al. (2017) similarly find that contractionary monetary policy shocks tend to increase the income of those who receive lots of financial income but lowers the incomes of business owners. Also, Coibion and Gorodnichenko (2012) narrate that monetary policy is highly persistent and policy shocks do propagate for a long time and this aligns with this present study's findings of a long-run effect of lending rate.

The study also employs the simultaneous quantile regression in this case for robustness checks and this is shown in Table 5.8. The findings reveal that increases in lending rate actually causes an increase in income inequality at all percent quantiles albeit statistically significant only at the lower and mid-quantiles. Thus, contractionary monetary policy causes an increase in income inequality and this appears statistically significant at the 10^{th}, 25^{th} and 50^{th} percent quantiles of the income inequality distribution and this is shown in Model 19, Model 20 & Model 21 respectively. This finding is in line with the results of Coibion et al. (2017) and Furceri et al. (2018) who find that contractionary monetary policy increases income inequality. This finding also supports the savings redistribution channel argument which explains that an increase in interest rate will be of more benefit to savers (surplus fund holders) than borrowers (those in need of funds) since savers are generally considered to be wealthier than borrowers. This is likely to widen the income inequality gap.

Table 5. 7: The Effects of Monetary Policy on Income Inequality

VARIABLES	MODEL 16	MODEL 17	MODEL 18
Lag of Income inequality	0.998***	1.049***	1.046***
	(0.043)	(0.021)	(0.020)
Monetary policy interest rate	-0.001	--	--
	(0.005)		
Lending interest rate	--	-0.006***	--
		(0.002)	
Deposit interest rate	--	--	0.002
			(0.005)
Real GDP per capita	0.041	0.316	0.477
	(1.603)	(0.916)	(0.653)
Real GDP per capita square	-0.004	-0.023	-0.031
	(0.112)	(0.068)	(0.046)
Political globalisation	-0.005	0.002	0.002
	(0.008)	(0.003)	(0.003)
Democracy - polity2	0.018	-0.011	-0.010
	(0.012)	(0.008)	(0.007)
Trade openness	0.234	0.137	0.186
	(0.354)	(0.162)	(0.165)
FDI	-0.002	0.003	0.002
	(0.006)	(0.003)	(0.003)
Age dependency ratio	-0.008	-0.013**	-0.011***
	(0.009)	(0.006)	(0.004)
Population growth	-0.033	0.081**	0.087
	(0.142)	(0.031)	(0.057)
School enrollment rate	0.002	-0.004	-0.003
	(0.003)	(0.003)	(0.004)
Unemployment	-0.015	-0.025*	-0.026*
	(0.017)	(0.013)	(0.014)
Gross capital formation	-0.012**	-0.007**	-0.006*
	(0.005)	(0.003)	(0.003)
Natural resource rent	-0.004	0.002	-0.000
	(0.006)	(0.006)	(0.005)
Constant	1.220	-1.945	-2.796
	(8.583)	(3.152)	(2.282)
Observations	128	328	361
Number of countries	17	33	36

Number of instruments	16	16	16
Wald test (Prob > F)	0.000	0.000	0.000
AR(1):(Pr > z)	-1.67(0.094)	-1.17(0.243)	-1.51(0.132)
AR(2):(Pr > z)	-0.56(0.577)	-0.99(0.322)	-0.85(0.396)
Sargan test:(Prob > chi2)	12.09(0.001)	2.03(0.154)	6.31(0.012)
Hansen test: (Prob > chi2)	2.84(0.092)	0.69(0.406)	2.09(0.148)

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 Model 16, 17 & 18 discuss the effects of monetary policy rate, lending rate and deposit rate on income inequality respectively.

Table 5. 8: The Effects of Monetary Policy on Income Inequality --- Quantile Regression

VARIABLES	MODEL 19	MODEL 20	MODEL 21	MODEL 22	MODEL 23
	0.10	**0.25**	**0.50**	**0.75**	**0.90**
Lending rate	**0.128*****	**0.076*****	**0.0624*****	**0.024**	**0.024**
	(0.029)	(0.026)	(0.022)	(0.037)	(0.047)
Real GDP per capita	8.609	10.67	-19.80	-37.29***	-24.91***
	(7.730)	(12.12)	(15.30)	(7.598)	(6.574)
Real GDP per capita^2	-0.740	-0.866	1.552	2.776***	1.880***
	(0.591)	(0.862)	(1.131)	(0.535)	(0.446)
Political globalization	-0.076	-0.107***	-0.025	-0.044	-0.122***
	(0.048)	(0.037)	(0.039)	(0.033)	(0.036)
Democracy - polity2	0.064	0.199	0.096	-0.035	-0.085
	(0.069)	(0.140)	(0.082)	(0.059)	(0.058)
Trade openness	-1.525	-1.864	0.757	1.729	-1.763
	(1.537)	(3.333)	(2.774)	(2.508)	(2.448)
FDI	-0.007	-0.022	-0.004	0.036	0.088*
	(0.055)	(0.067)	(0.093)	(0.067)	(0.048)
Age dependency ratio	0.027	0.230*	0.200***	0.056	-0.009
	(0.103)	(0.124)	(0.062)	(0.069)	(0.051)
Population growth	0.282	-2.116	-0.646	-0.423	-0.816*
	(0.945)	(1.464)	(0.678)	(0.437)	(0.493)
School enrollment	0.049	0.113***	-0.001	0.009	0.054
	(0.051)	(0.042)	(0.036)	(0.033)	(0.035)
Unemployment	0.189*	0.355	0.454***	0.208**	0.169**
	(0.104)	(0.220)	(0.126)	(0.095)	(0.079)
Gross capital formation	0.005	0.064	0.003	0.016	0.029
	(0.036)	(0.041)	(0.047)	(0.037)	(0.034)
Natural resource rent	-0.171***	-0.135**	-0.280***	-0.272***	-0.229***
	(0.036)	(0.066)	(0.055)	(0.071)	(0.045)
Constant	12.35	-7.870	88.69*	167.1***	137.7***
	(23.61)	(43.64)	(50.38)	(24.06)	(20.82)

Observations	335	335	335	335	335
Pseudo R^2	0.276	0.259	0.353	0.511	0.601

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

5.6 Conclusion and Recommendations

Income inequality has become a global defining challenge and continues to be one of the focal issues in the Sustainable Development Goals. This study comprehensively examines the roles of fiscal and monetary policies in income redistribution in Africa. The paper uses fiscal redistribution, total tax revenue, direct taxes, indirect taxes, property tax, government final consumption expenditure, expenditure on education, expenditure on primary, secondary and tertiary education as indicators of fiscal policy. It also uses monetary policy rate, lending rate and deposit interest rate as alternative measures of monetary policy. The study finds evidence that supports the notion that direct taxes are more progressive and able to provide both short and long run mitigation for economic inequality while indirect taxes and property tax have income unequalizing effects in Africa. Furthermore, the paper finds government spending on basic education to have income equalizing effects while spending on secondary and tertiary education appear income unequalizing. Also, some form of relationship exists between contractionary monetary policy and income inequality in Africa. Lastly, the paper finds evidence of the existence of the inverted U-shape Kuznets curve in the sample.

The paper suggests that tax reforms should be geared towards broadening the tax base with a particular focus on making the tax structure more progressive if income redistribution is of significance in tax administration in Africa. Thus, efforts need to be put in place to roll in more direct taxes. Also, there should be greater improvement in compliance in paying property taxes while enrolling more households in the property tax net. Furthermore, a more equitable redistribution of household income can be enforced through higher spending on basic education.

Monetary policy authorities should also take notice of the unintended redistributive effects of contractionary monetary policy.

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Introduction

The focus of this last chapter is to provide a summary of all the key findings from the four empirical papers. The chapter then concludes the study, provides some recommendations and few directions for future research.

6.2 Summary of Findings

This thesis contains four empirical papers on the broad theme, fiscal & monetary policy, climate change and income inequality in Africa. The study sampled 52 African countries over the period 1990 – 2017. The scope of this study is restricted by data limitations and unavailability of certain key indicators and variables. The study broadly deploys two-step system and difference Generalized Method of Moments estimation approach. However, other techniques such as fixed effects, random effects, quantile regression, Panel VECM and Panel VAR are used for robustness. The summary of each of the four empirical papers is presented next.

The first empirical paper is titled the implications of climate change and extreme weather events for fiscal balance and fiscal policy in Africa. The essence of this paper is to determine the effects of climate change and extreme weather events on fiscal balance and the resultant effect on fiscal policy formulation in Africa. The paper also sought to find how institutions and adaptive capacity moderate the effects of climate change and weather events on fiscal balance. The findings show that climate change which is measured by temperature change anomaly worsens the fiscal balance in Africa. Thus, increases in temperature which implies a warmer climate results to an increase in fiscal deficit in Africa. Also, large scale or extreme weather events exert a significance deteriorating influence on fiscal deficit in Africa due to the damage to property, persons and loss of lives. Furthermore, African countries with stronger institutions are more resilient to the impacts of climate change and extreme weather events than those without. Institutional quality indicators such as effective governments, quality regulations, voice and accountability systems moderate the effects of extreme weather events on fiscal balance.

The implications of extreme weather events for inflation and monetary policy in Africa is the title of the second empirical paper. This paper investigates the effects that extreme weather event has on food price inflation and headline inflation. It also examines the effects of drought and flood on food price inflation and headline inflation. Furthermore, the second paper empirically examines if agricultural production/productivity could serve as a conduit through which extreme weather events may impact food prices and general price levels. The findings reveal that large scale or extreme weather events cause a rise in headline inflation. Also there exists a bi-directional causality between extreme weather events and inflation in the long run. Drought also causes a hike in headline inflation. Also, the paper find drought and flood to cause a statistically significant increase in food price inflation. Furthermore, agricultural productivity was found to serve as a perfect mediator through which extreme weather event causes a rise in headline inflation.

The third paper is titled do weather events affect income inequality in Africa? This paper investigates the effects of weather events on income inequality. It also examines the moderating roles of institutions and adaptive capacity on income inequality. The paper finds the existence of a non-monotonic U-shape relationship between weather events and income inequality in Africa. Similarly, flood also shows a non-monotonic U-shape effect on income inequality. However, the results of the quantile regression show that weather event increases income inequality at the 25th

and 50th percent quantile. The papers also finds that stronger institutions help reduce the impact of weather events on income inequality.

The fourth and final paper on the distributional effectiveness of fiscal and monetary policies aims at identifying the roles that taxes and government expenditure play in income redistribution. It uses variants of taxes and government expenditure. It also investigates the unintended distributional effects of monetary policy in Africa. The findings show that total tax revenue and direct tax reduce income inequality while property tax increases income inequality in Africa. The results of the property tax is corroborated by both system GMM and quantile regression techniques. Using, Panel VAR, taxes does granger cause inequality but the converse does not hold. Indirect tax was found to be statistically insignificant. The results of the expenditure side of fiscal policy indicates that total government expenditure and total general government spending on education have no statistically significant effect on income inequality. However, government spending on primary education reduces income inequality while government spending on secondary and tertiary education increase income inequality. The results of the monetary policy side show that monetary policy rate has no statistical significant effect on income inequality but an increase in lending rate reduces income inequality.

6.3 Conclusion

The impacts of climate change are being felt world-wide in the form of changes in average temperature and the occurrence of extreme weather events. Even though highly industrialized countries are responsible for a chunk of the global climatic variabilities through carbon emissions, studies have shown that African countries bear the most brunt of these climate change impacts. And this is because most African countries have poor fiscal management practices and limited fiscal space to accommodate the excesses of climate change. They also have less adaptive mechanisms and depend heavily on less mechanized agriculture systems which is known to be climate-sensitive. This study investigates the effects climate change and weather events have on fiscal balance, inflation and income inequality. It also investigates the roles of fiscal and monetary policies in ensuring income redistribution in Africa.

The findings show that climate change and weather events deteriorates fiscal balance in Africa. However, African countries with relatively robust institutions endure less impacts of climate change and extreme weather events. The findings also reveal that extreme weather events cause a rise in headline inflation and this may have implications for the price and output stability function of central banks. Weather events also increase income inequality. Furthermore, the findings show that direct tax reduce income inequality while property tax increases income inequality in Africa. Indirect tax was, however, found to be statistically insignificant. Also, government spending on primary education reduces income inequality while government spending on secondary and tertiary education increase income inequality. Finally, increases in lending rate increases income inequality.

The study concludes that African countries need to incorporate climate change adaptation and mitigation measures in their annual budgetary allocations. Also, African countries need to boost their adaptive capacities and deploy robust institutional structures to curtail the impacts of climate change on economic indicators.

6.4 Recommendations

African countries should tighten their fiscal consolidation efforts as climate change and weather events may prove to be a destabilizer to these efforts.

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. They should also put in place systems for adaptation against climate change impacts as adaptive capacities remain very weak.

The study suggests that African governments should form a coalition with one strong voice in the fight against climate change for much larger funds to be allocated to the continent. African countries should also lead the charge against carbon emissions worldwide. This is because African countries emit less carbon but bear most of the brunt of climate change impacts.

A key policy recommendation of this thesis is that monetary policy authorities may need to consider the short and long run implications of supply shocks caused by extreme weather events on food prices and the general price level. Anchoring inflation expectations should be a major drive of the policy makers. Additionally, we suggest that a buffer of food stuffs be kept on regular basis to serve as respite in times of eventualities in order to anchor inflation.

The study also recommends that critical attention should be paid to climate change mitigation as the impending future impacts of climate change in the form of weather events appear gloomy for major economic and social indicators such as income inequality. Specifically, income inequality concerns should not be ignored in the global climate change discussions.

The study suggests that tax reforms should be geared towards broadening the tax base with a particular focus on making the tax structure more progressive if income redistribution is of significance in tax administration in Africa. Thus, efforts need to be put in place to roll in more direct taxes. Also, there should be greater improvement in compliance in paying property taxes while enrolling more households in the property tax net.

Furthermore, a more equitable redistribution of household income can be enforced through higher spending on basic education. Monetary policy authorities should also take notice of the unintended redistributive effects of contractionary monetary policy.

6.5 Areas for Future Research

One grey area that needs to be further examined is the implications climate change and weather events have for economic growth and poverty in the context of Africa.

An unavoidable policy instrument to help in the fight against climate change is climate finance and more specifically, private financing flows. Private climate finance plays a pivotal role in climate change adaptation and mitigation but empirical evidence appears unavailable in the African context. This could be a potential area for future research. Future research could gauge the systems and mechanisms in place to monitor and track private funding of climate change in Africa.

Future studies can use alternative measures of income inequality such as the Atkinson index and Palma ratio to assess the effects of weather events on income inequality and the distributional effects of fiscal and monetary policies.

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APPENDIX

Appendix 1. 1: 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		

Appendix 2: Panel VECM

Panel Cointegration Test for Inflation & Weather Event

Appendix 2.1 Pedroni Residual Cointegration Test
Series: Inflation Weather Event
Sample: 1990 2017
Included observations: 1456
Cross-sections included: 35 (17 dropped) in non-parametric (PP) test;
30 (22 dropped) parametric (ADF) test
Null Hypothesis: No cointegration
Trend assumption: No deterministic trend
Automatic lag length selection based on SIC with lags from 0 to 6
Newey-West automatic bandwidth selection and Bartlett kernel

Alternative hypothesis: common AR coefs. (within-dimension)

	Statistic	Prob.	Weighted Statistic	Prob.
Panel v-Statistic	3.803301	0.0001	0.219674	0.4131
Panel rho-Statistic	-9.471693	0.0000	-8.806152	0.0000
Panel PP-Statistic	-10.86239	0.0000	-9.052450	0.0000
Panel ADF-Statistic	-8.825631	0.0000	-7.381283	0.0000

Alternative hypothesis: individual AR coefs. (between-dimension)

	Statistic	Prob.
Group rho-Statistic	-4.751278	0.0000
Group PP-Statistic	-8.504781	0.0000
Group ADF-Statistic	-5.548919	0.0000

The cointegration test using the Pedroni Residual Cointegration test rejects the null hypothesis of no cointegration. Thus, there is cointegration and hence a long run relationship may exists between headline inflation and extreme weather events. Therefore we can proceed with Panel VECM to determine both short and long run relationships.

Appendix 2.2:Vector Error Correction Estimates
Sample (adjusted): 1993 2017
Included observations: 821 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1	
Inflation(-1)	1.000000	
Weather Event (-1)	-3.631844 (0.39072) [-9.29527]	
C	-0.685900	
Error Correction:	**D(Inflation)**	**D(Weather Event)**
CointEq1	-0.066907 (0.01571) [-4.25811]	0.093437 (0.01126) [8.29945]
D(Inflation(-1))	-0.475174 (0.03331) [-14.2639]	-0.022974 (0.02387) [-0.96253]
D(Inflation(-2))	-0.285721 (0.03042) [-9.39177]	0.022344 (0.02180) [1.02505]
D(Weather Event(-1))	-0.225018 (0.05886) [-3.82289]	-0.336403 (0.04217) [-7.97664]
D(Weather Event(-2))	-0.057736 (0.05041) [-1.14541]	-0.195226 (0.03612) [-5.40550]
C	-0.061312 (0.02566) [-2.38983]	0.010470 (0.01838) [0.56960]
R-squared	0.268767	0.323707
Adj. R-squared	0.264281	0.319558
Sum sq. resids	435.9724	223.8127
S.E. equation	0.731393	0.524039
F-statistic	59.91120	78.01973
Log likelihood	-905.1249	-631.4161

Akaike AIC	2.219549	1.552780
Schwarz SC	2.253974	1.587205
Mean dependent	-0.026779	0.008526
S.D. dependent	0.852697	0.635284

Determinant resid covariance (dof adj.)	0.146383
Determinant resid covariance	0.144251
Log likelihood	-1535.086
Akaike information criterion	3.773657
Schwarz criterion	3.853983

The first part is the cointegration equation and then the error correction follows.

Appendix 2.3: Estimation Method: Least Squares
Sample: 1993 2017
Included observations: 876
Total system (unbalanced) observations 1697

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.066907	0.015713	-4.258112	0.0000
C(2)	-0.475174	0.033313	-14.26394	0.0000
C(3)	-0.285721	0.030422	-9.391773	0.0000
C(4)	-0.225018	0.058861	-3.822886	0.0001
C(5)	-0.057736	0.050407	-1.145414	0.2522
C(6)	-0.061312	0.025655	-2.389832	0.0170
C(7)	0.095196	0.010565	9.010611	0.0000
C(8)	-0.026107	0.022588	-1.155798	0.2479
C(9)	0.012685	0.020430	0.620903	0.5347
C(10)	-0.339505	0.040189	-8.447772	0.0000
C(11)	-0.203945	0.034404	-5.928000	0.0000
C(12)	0.009300	0.017531	0.530502	0.5958
Determinant residual covariance		0.140205		

Equation: D(Inflation) = C(1)*(Inflation(-1) - 3.63184363004
*Weather Event(-1) - 0.685899552973) + C(2)*D(Weather Event(
-1)) + C(3)*D(Inflation(-2)) + C(4)*D(Weather Event(-1)) +
C(5)*D(Weather Event(-2)) + C(6)
Observations: 821

R-squared	0.268767	Mean dependent var	-0.026779
Adjusted R-squared	0.264281	S.D. dependent var	0.852697
S.E. of regression	0.731393	Sum squared resid	435.9724
Durbin-Watson stat	1.990307		

Equation: D(Weather Event) = C(7)*(Inflation(-1) -
3.63184363004*Weather Event(-1) - 0.685899552973) + C(8)
*D(Inflation(-1)) + C(9)*D(Inflation(-2)) + C(10)
*D(Weather Event(-1)) + C(11)*D(Weather Event(-2)) + C(12)
Observations: 876

R-squared	0.335105	Mean dependent var	0.005708
Adjusted R-squared	0.331284	S.D. dependent var	0.631526

S.E. of regression	0.516430	Sum squared resid	232.0293
Durbin-Watson stat	2.092165		

The speed of adjustment is negative and statistically significant (C1). Thus, extreme weather events granger causes headline inflation in the long run.

Appendix 2.4: Wald Test:
System: Untitled

Test Statistic	Value	df	Probability
Chi-square	16.03188	2	0.0003

Null Hypothesis: C(4)=C(5)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(4)	-0.225018	0.058861
C(5)	-0.057736	0.050407

Restrictions are linear in coefficients.

We reject the null hypothesis of no short run granger causality in favour of the alternative hypothesis that there is a short run granger causality. Thus, extreme weather events granger causes inflation in the short run.

Appendix 2.5: Vector Error Correction Estimates
Sample (adjusted): 1993 2017
Included observations: 821 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1	
Weather Event(-1)	1.000000	
Inflation(-1)	-0.275342 (0.05480) [-5.02457]	
C	0.188857	
Error Correction:	D(EVENT_1_COUNT)	D(LNINFLATION)
CointEq1	-0.339349 (0.04089)	0.242997 (0.05707)

	[-8.29945]	[4.25811]
D(Weather Event(-1))	-0.336403	-0.225018
	(0.04217)	(0.05886)
	[-7.97664]	[-3.82289]
D(Weather Event(-2))	-0.195226	-0.057736
	(0.03612)	(0.05041)
	[-5.40550]	[-1.14541]
D(Inflation(-1))	-0.022974	-0.475174
	(0.02387)	(0.03331)
	[-0.96253]	[-14.2639]
D(Inflation(-2))	0.022344	-0.285721
	(0.02180)	(0.03042)
	[1.02505]	[-9.39177]
C	0.010470	-0.061312
	(0.01838)	(0.02566)
	[0.56960]	[-2.38983]
R-squared	0.323707	0.268767
Adj. R-squared	0.319558	0.264281
Sum sq. resids	223.8127	435.9724
S.E. equation	0.524039	0.731393
F-statistic	78.01973	59.91120
Log likelihood	-631.4161	-905.1249
Akaike AIC	1.552780	2.219549
Schwarz SC	1.587205	2.253974
Mean dependent	0.008526	-0.026779
S.D. dependent	0.635284	0.852697

Determinant resid covariance (dof adj.)	0.146383
Determinant resid covariance	0.144251
Log likelihood	-1535.086
Akaike information criterion	3.773657
Schwarz criterion	3.853983

Appendix 2.6: Estimation Method: Least Squares
Sample: 1993 2017
Included observations: 876
Total system (unbalanced) observations 1697

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.345739	0.038370	-9.010611	0.0000
C(2)	-0.339505	0.040189	-8.447772	0.0000
C(3)	-0.203945	0.034404	-5.928000	0.0000
C(4)	-0.026107	0.022588	-1.155798	0.2479
C(5)	0.012685	0.020430	0.620903	0.5347
C(6)	0.009300	0.017531	0.530502	0.5958
C(7)	0.242997	0.057067	4.258112	0.0000
C(8)	-0.225018	0.058861	-3.822886	0.0001
C(9)	-0.057736	0.050407	-1.145414	0.2522

C(10)	-0.475174	0.033313	-14.26394	0.0000
C(11)	-0.285721	0.030422	-9.391773	0.0000
C(12)	-0.061312	0.025655	-2.389832	0.0170
Determinant residual covariance		0.140205		

Equation: D(Weather Event) = C(1)*(Weather Event(-1) -
0.275342250897*Inflation(-1) + 0.188857126805) + C(2)
*D(Weather Event(-1)) + C(3)*D(Weather Event(-2)) + C(4)
*D(Inflation(-1)) + C(5)*D(Inflation(-2)) + C(6)
Observations: 876

R-squared	0.335105	Mean dependent var	0.005708
Adjusted R-squared	0.331284	S.D. dependent var	0.631526
S.E. of regression	0.516430	Sum squared resid	232.0293
Durbin-Watson stat	2.092165		

Equation: D(Inflation) = C(7)*(Weather Event(-1) -
0.275342250897*Inflation(-1) + 0.188857126805) + C(8)
*D(Weather Event(-1)) + C(9)*D(Weather Event(-2)) + C(10)
*D(Inflation(-1)) + C(11)*D(Inflation(-2)) + C(12)
Observations: 821

R-squared	0.268767	Mean dependent var	-0.026779
Adjusted R-squared	0.264281	S.D. dependent var	0.852697
S.E. of regression	0.731393	Sum squared resid	435.9724
Durbin-Watson stat	1.990307		

In order to test whether inflation also granger causes extreme weather events in the long run, we run similar results but with extreme weather events as dependent variable and inflation an independent variable. Since the (C1) is negative and significant, we can conclude that inflation granger causes extreme weather events in the long run.

Appendix 2.7: Wald Test:
System: Untitled

Test Statistic	Value	df	Probability
Chi-square	2.914015	2	0.2329

Null Hypothesis: C(4)=C(5)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(4)	-0.026107	0.022588
C(5)	0.012685	0.020430

Restrictions are linear in coefficients.

Based on the short run results, inflation does not granger cause extreme weather events in the short run as the P-value is not significant. In conclusion there is bi-directional causality between inflation and extreme weather events in the long run. But that is not the case in the short run as there is one-directional causality in the short run from extreme weather events to inflation and not vice versa.

Appendix 3: Panel VAR

Panel Cointegration Test for Gini (Income inequality) & Taxes

Appendix 3.1: Pedroni Residual Cointegration Test
Series: GINI TAXES
Sample: 1990 2017
Included observations: 1456
Cross-sections included: 25 (27 dropped)
Null Hypothesis: No cointegration
Trend assumption: No deterministic trend
Automatic lag length selection based on SIC with lags from 0 to 5
Newey-West automatic bandwidth selection and Bartlett kernel

Alternative hypothesis: common AR coefs. (within-dimension)

	Statistic	Prob.	Weighted Statistic	Prob.
Panel v-Statistic	-1.980977	0.9762	-1.471372	0.9294
Panel rho-Statistic	1.262236	0.8966	1.114158	0.8674
Panel PP-Statistic	0.048560	0.5194	0.497725	0.6907
Panel ADF-Statistic	-0.075873	0.4698	-0.010404	0.4958

Alternative hypothesis: individual AR coefs. (between-dimension)

	Statistic	Prob.
Group rho-Statistic	2.302183	0.9893
Group PP-Statistic	0.182519	0.5724
Group ADF-Statistic	-0.809482	0.2091

Appendix 3.2: Kao Residual Cointegration Test
Series: GINI TAXES
Sample: 1990 2017
Included observations: 1456
Null Hypothesis: No cointegration
Trend assumption: No deterministic trend
Automatic lag length selection based on SIC with a max lag of 0
Newey-West automatic bandwidth selection and Bartlett kernel

	t-Statistic	Prob.
ADF	-0.653685	0.2567
Residual variance	0.056377	
HAC variance	0.191614	

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RESID)
Method: Least Squares
Sample (adjusted): 1991 2016
Included observations: 381 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESID(-1)	-0.085242	0.015309	-5.568101	0.0000

R-squared	0.073027	Mean dependent var	-0.014289
Adjusted R-squared	0.073027	S.D. dependent var	0.280386
S.E. of regression	0.269954	Akaike info criterion	0.221495
Sum squared resid	27.69266	Schwarz criterion	0.231843
Log likelihood	-41.19471	Hannan-Quinn criter.	0.225600
Durbin-Watson stat	1.112896		

The cointegration test using the Pedroni and Kao Residual Cointegration tests fails to reject the null hypothesis of no cointegration. Thus, taxes and inequality are not cointegrated and hence a long run relationship does not exists. This outcome means that Panel VAR can be run.

Appendix 3.3: Dependent Variable: GINI
Method: Panel Least Squares
Sample (adjusted): 1992 2016
Periods included: 25
Cross-sections included: 25
Total panel (unbalanced) observations: 363

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.673153	0.526507	3.177839	0.0016
GINI(-1)	0.966789	0.011152	86.69178	0.0000
TAXES	0.000396	0.005840	0.067770	0.9460
TAXES(-2)	-0.015704	0.006390	-2.457413	0.0145

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.999405	Mean dependent var	44.10854
Adjusted R-squared	0.999357	S.D. dependent var	6.958346
S.E. of regression	0.176461	Akaike info criterion	-0.557432
Sum squared resid	10.43143	Schwarz criterion	-0.257038
Log likelihood	129.1740	Hannan-Quinn criter.	-0.438027
F-statistic	20835.27	Durbin-Watson stat	0.501606
Prob(F-statistic)	0.000000		

First panel fixed effect is estimated, then random effects

Appendix 3.4: Dependent Variable: GINI
Method: Panel EGLS (Cross-section random effects)
Sample (adjusted): 1992 2016
Periods included: 25
Cross-sections included: 25
Total panel (unbalanced) observations: 363
Swamy and Arora estimator of component variances

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.070167	0.205761	-0.341013	0.7333
GINI(-1)	1.002255	0.004581	218.7887	0.0000
TAXES	0.003864	0.005566	0.694314	0.4879
TAXES (-2)	-0.008659	0.005831	-1.485147	0.1384

Effects Specification

	S.D.	Rho
Cross-section random	0.160654	0.4532
Idiosyncratic random	0.176461	0.5468

Weighted Statistics

R-squared	0.992291	Mean dependent var	11.95645
Adjusted R-squared	0.992226	S.D. dependent var	2.723476
S.E. of regression	0.180360	Sum squared resid	11.67815

F-statistic	15402.70	Durbin-Watson stat	0.456774
Prob(F-statistic)	0.000000		

Unweighted Statistics

R-squared	0.998819	Mean dependent var	44.10854
Sum squared resid	20.70579	Durbin-Watson stat	0.257623

This the results for the random effects.

Appendix 3.5: Correlated Random Effects - Hausman Test
Equation: Untitled
Test cross-section random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	16.105250	3	0.0011

Cross-section random effects test comparisons:

Variable	Fixed	Random	Var(Diff.)	Prob.
GINI(-1)	0.966789	1.002255	0.000103	0.0005
TAXES	0.000396	0.003864	0.000003	0.0499
TAXES (-2)	-0.015704	-0.008659	0.000007	0.0071

Cross-section random effects test equation:
Dependent Variable: GINI
Method: Panel Least Squares
Date: 12/20/22 Time: 05:38
Sample (adjusted): 1992 2016
Periods included: 25
Cross-sections included: 25
Total panel (unbalanced) observations: 363

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.673153	0.526507	3.177839	0.0016
GINI(-1)	0.966789	0.011152	86.69178	0.0000
TAXES	0.000396	0.005840	0.067770	0.9460
TAXES (-2)	-0.015704	0.006390	-2.457413	0.0145

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.999405	Mean dependent var	44.10854
Adjusted R-squared	0.999357	S.D. dependent var	6.958346
S.E. of regression	0.176461	Akaike info criterion	-0.557432
Sum squared resid	10.43143	Schwarz criterion	-0.257038

Log likelihood	129.1740	Hannan-Quinn criter.	-0.438027
F-statistic	20835.27	Durbin-Watson stat	0.501606
Prob(F-statistic)	0.000000		

Based on the Hausman test, random effect is rejected in favour of the fixed effects.

Appendix 3.6: Dependent Variable: GINI
Method: Panel Least Squares
Sample (adjusted): 1992 2016
Periods included: 25
Cross-sections included: 25
Total panel (unbalanced) observations: 363

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.673153	0.526507	3.177839	0.0016
GINI(-1)	0.966789	0.011152	86.69178	0.0000
TAXES	0.000396	0.005840	0.067770	0.9460
TAXES(-2)	-0.015704	0.006390	-2.457413	0.0145

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.999405	Mean dependent var	44.10854
Adjusted R-squared	0.999357	S.D. dependent var	6.958346
S.E. of regression	0.176461	Akaike info criterion	-0.557432
Sum squared resid	10.43143	Schwarz criterion	-0.257038
Log likelihood	129.1740	Hannan-Quinn criter.	-0.438027
F-statistic	20835.27	Durbin-Watson stat	0.501606
Prob(F-statistic)	0.000000		

Granger causality test

Appendix 3.7: Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	4.798843	(2, 335)	0.0088
Chi-square	9.597686	2	0.0082

Null Hypothesis: C(3)=C(4)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(3)	0.000396	0.005840
C(4)	-0.015704	0.006390

Restrictions are linear in coefficients.

The null hypothesis is that taxes does not granger cause inequality. The evidence based on the results of the Wald test using the Chi-square shows that taxes does granger cause income inequality. The next test is see if there is a reverse causality.

Appendix 3.8: Dependent Variable: TAXES
Method: Panel Least Squares
Sample (adjusted): 1992 2016
Periods included: 25
Cross-sections included: 25
Total panel (unbalanced) observations: 369

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	9.541504	3.716475	2.567353	0.0107
TAXES(-1)	0.818850	0.036231	22.60074	0.0000
GINI	-0.320226	0.254752	-1.257013	0.2096
GINI(-2)	0.176643	0.238795	0.739729	0.4600

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.976717	Mean dependent var	16.65839
Adjusted R-squared	0.974873	S.D. dependent var	8.307789
S.E. of regression	1.316904	Akaike info criterion	3.461291
Sum squared resid	591.3745	Schwarz criterion	3.758046
Log likelihood	-610.6083	Hannan-Quinn criter.	3.579177
F-statistic	529.8041	Durbin-Watson stat	2.235574
Prob(F-statistic)	0.000000		

These are the estimates for Fixed Effects

Appendix 3.9: Dependent Variable: TAXES
Method: Panel EGLS (Cross-section random effects)
Sample (adjusted): 1992 2016
Periods included: 25
Cross-sections included: 25
Total panel (unbalanced) observations: 369
Swamy and Arora estimator of component variances

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.133339	0.451765	0.295151	0.7680
TAXES(-1)	1.000933	0.008971	111.5683	0.0000
GINI	-0.142310	0.158509	-0.897802	0.3699
GINI(-2)	0.144358	0.160853	0.897456	0.3701

Effects Specification		S.D.	Rho
Cross-section random		0.000000	0.0000
Idiosyncratic random		1.316904	1.0000

Weighted Statistics

R-squared	0.973787	Mean dependent var	16.65839
Adjusted R-squared	0.973572	S.D. dependent var	8.307789
S.E. of regression	1.350583	Sum squared resid	665.7871
F-statistic	4519.797	Durbin-Watson stat	2.382296
Prob(F-statistic)	0.000000		

Unweighted Statistics

R-squared	0.973787	Mean dependent var	16.65839
Sum squared resid	665.7871	Durbin-Watson stat	2.382296

These are the estimates for Random Effects

Appendix 3.10: Correlated Random Effects - Hausman Test
Equation: Untitled
Test cross-section random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	27.253617	3	0.0000

** WARNING: estimated cross-section random effects variance is zero.

Cross-section random effects test comparisons:

Variable	Fixed	Random	Var(Diff.)	Prob.
TAXES(-1)	0.818850	1.000933	0.001232	0.0000
GINI	-0.320226	-0.142310	0.039773	0.3723
GINI(-2)	0.176643	0.144358	0.031149	0.8549

Cross-section random effects test equation:
Dependent Variable: TAXES
Method: Panel Least Squares
Sample (adjusted): 1992 2016
Periods included: 25
Cross-sections included: 25
Total panel (unbalanced) observations: 369

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	9.541504	3.716475	2.567353	0.0107
TAXES(-1)	0.818850	0.036231	22.60074	0.0000

GINI	-0.320226	0.254752	-1.257013	0.2096
GINI(-2)	0.176643	0.238795	0.739729	0.4600

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.976717	Mean dependent var	16.65839
Adjusted R-squared	0.974873	S.D. dependent var	8.307789
S.E. of regression	1.316904	Akaike info criterion	3.461291
Sum squared resid	591.3745	Schwarz criterion	3.758046
Log likelihood	-610.6083	Hannan-Quinn criter.	3.579177
F-statistic	529.8041	Durbin-Watson stat	2.235574
Prob(F-statistic)	0.000000		

The Hausman test is performed to determine which model to use. The null hypothesis of random effect being more appropriate is rejected and hence the fixed effect is preferred.

Appendix 3.11: Dependent Variable: TAXES
Method: Panel Least Squares
Sample (adjusted): 1992 2016
Periods included: 25
Cross-sections included: 25
Total panel (unbalanced) observations: 369

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	9.541504	3.716475	2.567353	0.0107
TAXES (-1)	0.818850	0.036231	22.60074	0.0000
GINI	-0.320226	0.254752	-1.257013	0.2096
GINI(-2)	0.176643	0.238795	0.739729	0.4600

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.976717	Mean dependent var	16.65839
Adjusted R-squared	0.974873	S.D. dependent var	8.307789
S.E. of regression	1.316904	Akaike info criterion	3.461291
Sum squared resid	591.3745	Schwarz criterion	3.758046
Log likelihood	-610.6083	Hannan-Quinn criter.	3.579177
F-statistic	529.8041	Durbin-Watson stat	2.235574
Prob(F-statistic)	0.000000		

The fixed effect estimates are presented here.

Appendix 3.12: Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	1.858182	(2, 341)	0.1575
Chi-square	3.716364	2	0.1560

Null Hypothesis: C(3)=C(4)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(3)	-0.320226	0.254752
C(4)	0.176643	0.238795

Restrictions are linear in coefficients.

The wald test is hence performed to determine if income inequality does granger cause taxes. The null hypothesis is not rejected that income inequality does not granger cause taxes. Thus, there is no evidence of bi-directional causality.