UNIVERSITY OF CAPE COAST

# URBANISATION, CLIMATE CHANGE AND ECONOMIC GROWTH: EVIDENCE FROM SUB-SAHARA AFRICA

MBA AWUDU AZUMBILLA

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# URBANISATION, CLIMATE CHANGE AND ECONOMIC GROWTH: EVIDENCE FROM SUB-SAHARA AFRICA

BY

MBA AWUDU AZUMBILLA

Thesis submitted to the Department of Economic Studies of the School of Economics of the College of Humanities and Legal Studies, University of Cape Coast in partial fulfillment of the requirements for the award of Master of Philosophy degree in Economics.

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# DECLARATION

## Candidate's Declaration

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature: ………………………… Date……..................

Name: Mba Awudu Azumbilla

## Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature: ……………....... Date……………….......

Name: Dr. Isaac Bentum-Ennin

Co-Supervisor's Signature: ……………........ Date…………………

Name: Dr. Benedict Jr Afful

# ABSTRACT

The study contributes to literature by investigating the effect of climate change and urbanisation on economic growth in Sub-Sahara Africa using data on two climate variables, as well as new measure of urbanisation proposed by Gross and Ouyang (2022). Employing annual panel data from 32 Sub-Sahara African countries over 21-year period and adopting dynamic estimation techniques, the study established that urbanisation, temperature and precipitation are statistically significant determinants of economic growth in the region. Again, the study revealed that urbanisation and climate change variables have non-linear relationships with economic growth in SSA. However, all the climate change variables are effective in playing the moderating role of urbanisation to affect economic growth. The study recommend that the region's governments not only have a responsibility to work constructively for a global agreement to manage climate change, but should also provide an enabling policy framework covering management, planning and service delivery functions for adaptation that facilitate and support local institutions and other actor's efforts. Removing barriers to rural-to-urban migration could allow for economic growth, but the economic benefits will be far greater with supportive policies, market creation and infrastructure investments. Additionally, Governments should seek out ways of enabling forms of urbanisation that contribute to growth, poverty reduction and environmental sustainability, rather than encouraging (or discouraging) urbanisation per se.

## KEY WORDS

Climate Change

Economic Growth

Precipitaion.

Sub-Sahara Africa

Urbanisation

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# DEDICATION

To my brothers and friends.

# LIST OF ACRONYMS

| | |
|---|---|
| GMM | General Method of moment |
| Sys GMM | System General Method of Moment |
| FDI | Foreign Direct Investment |
| SSA | sub-Saharan Africa |
| GDP | Gross Domestic Product |
| US | United States of America |
| AFDB | African Development Bank |
| IPPC | Intergovernmental Panel on Climate Change |
| CRED | Climate Related Disease |
| UHI | Urban Heat Islands |
| UNICEF | United Nation International Children Fund |
| ABM | Agent Based Model |
| VEC | Vector Error Correction |
| VECM | Vector Error Correction Model |
| UNDP | United Nation Development Programme |
| URBANG | Urbanisation Growth |
| FCCC | Framework on Conventional Climate Change |
| PCA | Principal Component Analysis |
| WDI | World Development Indicators |
| NASA | National Aeronautical and Space Agency |
| LLC | Levin-Lin-Chu |
| IPS | Im-Pesaran-Shin |

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# CHAPTER ONE

# INTRODUCTION

## Background of the study

The issue of climate change and urbanisation in sub-Saharan Africa and the world at large has become a major concern. Urbanisation, climate change, and economic growth represent three interrelated factors that are shaping the contemporary dynamics of Sub-Saharan Africa (Seto, K. C., Güneralp, B., & Hutyra, L. R. (2012).)

This vast and diverse region is experiencing a profound transformation as its population increasingly gravitates towards urban centers. These urbanisation trends have significant implications for the socio-economic and environmental landscape of the region, intersecting with the challenges posed by climate change (Harrod, R. P., & Martin, D. L. 2014). Understanding the complex relationship between urbanisation, climate change, and economic growth is critical for policymakers, researchers, and development practitioners working in Sub-Saharan Africa.

Sub-Saharan Africa is currently witnessing one of the most rapid urbanisation processes in the world. The region's urban population is expected to double by 2030, primarily driven by rural-to-urban migration, natural population growth, and economic opportunities within cities (Agyemang, 2018). As cities expand, the demand for infrastructure, housing, energy, and transportation skyrockets, often surpassing the capacity of governments to provide necessary services (World Bank, 2016). This urbanisation, while contributing to economic growth and technological advancement, simultaneously exerts immense pressure on the environment, resulting in issues like air pollution, water contamination, and inadequate access to basic services (World Resources Institute, 2019).

Concurrently, Sub-Saharan Africa faces the considerable challenge of climate change, characterized by increased frequency and intensity of extreme weather events, water scarcity, and rising temperatures (IPCC, 2018). The region is particularly vulnerable due to its heavy reliance on agriculture and limited resources for adapting to and mitigating the impacts of climate change (United Nations, 2019). Climate change effects such as droughts, floods, and changing disease patterns have a direct bearing on food security, public health, and economic stability in Sub-Saharan Africa, making it imperative to address these challenges in an integrated manner (Niang *et al*., 2014).

The intersection of urbanisation, climate change, and economic growth is a complex and multifaceted one. On one hand, urbanisation can stimulate economic growth by concentrating human capital, fostering innovation, and creating opportunities for entrepreneurship (Davis, 2019). On the other hand, rapid urbanisation can exacerbate environmental pressures and vulnerabilities to climate change, potentially impeding sustainable development. Therefore, there is a pressing need to investigate how these intertwined dynamics influence each other and whether urbanisation can be harnessed as a driver of sustainable development in Sub-Saharan Africa.

This research seeks to explore the intricate relationship between urbanisation, climate change, and economic growth, using evidence from Sub-Saharan Africa. By focusing on this region, which exemplifies both the challenges and opportunities associated with these global issues, we can gain valuable insights into potential policy interventions and strategies to promote sustainable urbanisation, economic development, and climate resilience (Oyebamiji et al., 2021).

It is important to recognize that Sub-Saharan Africa's experience with urbanisation, climate change, and economic growth is highly diverse, with regional variations in environmental conditions, economic development, and urbanisation rates. This complexity underscores the need for nuanced, context-specific approaches to address the challenges and opportunities presented by these interconnected forces.

Sub-Saharan Africa's urbanisation trends are not uniform, with variations between countries and cities. Some cities are experiencing rapid expansion, while others are growing at a slower pace. Understanding the specific dynamics at play in different urban centers is essential for tailoring effective policies. Moreover, it is critical to consider the demographic and socio-economic characteristics of those migrating to cities, as this can influence the impact of urbanisation on economic growth and climate resilience (Bocquier *et al*., 2019).

In the context of climate change, Sub-Saharan Africa is grappling with the need to both mitigate greenhouse gas emissions and adapt to the changing climate. This requires not only local and national strategies but also international cooperation and support. Adaptation measures, such as building resilient infrastructure and improving disaster preparedness, are vital, especially for urban areas that are increasingly exposed to climate-related risks (IPCC, 2014).

Additionally, the role of economic growth cannot be understated. While urbanisation can be a driver of economic development, it is essential to ensure that this growth is inclusive, sustainable, and resilient to climate change. Policies that promote green technologies, sustainable urban planning, and job creation in both formal and informal sectors are crucial in this regard (Adelekan *et al.*, 2020).

A large number of statistics from both developed and developing countries, as well as economic zones, support the significant link between urbanisation and economic growth (World Bank, 2016). The United States, China, and a few Latin American countries are examples. The rate of urbanisation in the United States went from 28% in 1880 to 81 percent in 2006. That's a 53 percent rise in 126 years. GDP per capita increased from 3,380 to 37,832 current US dollars during that time period, an increase of 34,452 current US dollars (World Bank, 2016). Similarly, China's urban growth rate increased from 16 percent in 1960 to 39 percent in 2004, representing a 51 percent rise over 44 years. China's GDP per capita increased from 448 to 7,593.5 US dollars throughout that time (World Bank, 2016).

The GDP per capita in Latin American countries with urbanisation rates ranging from 20% to 40% was between $10,000 and 20,000 current US dollars. These findings hold true in Europe and Central Asia as well. 20,000 US dollars, corresponding to a 50% average urban growth rate, versus 42,500 US dollars when the urbanisation rate is between 60% and 95% (World Bank, 2016).

According to Mayaki *et al.* (2017), Africa is urbanizing at an unprecedented rate, accompanied by a demographic surge that has never been seen before. Since 1995, the number of people living in cities has doubled, reaching 472 million in 2015. Around 56% of Africans are anticipated to reside in cities by 2050. According to Mayaki *et al*. (2017), Africa's urbanisation provides enormous promise for speeding structural transformation that drives economic growth, citing the African Economic Outlook 2016. This is the case because sustained and growing demand in African cities requires massive investments in urban infrastructure by 2050. Indeed, increased agricultural productivity, industrialization, services fueled by an expanding middle class, and foreign direct investment in urban corridors are all viable sources of economic expansion.

Unfortunately, while urbanisation has been advantageous to high-income countries' economic growth, such impacts do not apply to developing countries (See Bala, 2009). This viewpoint differs from that of scholars like Bertinelli and Strobl (2007) and Henderson (2003), who claimed that low levels of economic growth had a significant impact. According to Frick and Pose (2018), in cases of low economic development, particularly in Sub-Saharan Africa, urban concentration appears to be completely divorced from the country's economic performance. With a record urbanisation rate of 40% recorded in 2016, it appears that Sub-Saharan Africa's GDP per capita is stuck at roughly $3,750 in current US dollars (World Bank, 2016). This implies that there has been little or no significant increase in the average income or economic well-being of the population despite the urbanisation trend in 2016. This lack of substantial change in GDP per capita could be indicative of various economic and developmental challenges faced by the region. Thus, it appears, without extending to all African cities, that the "drive mechanism" linking urbanisation and economic development has, until now, worked less well in Africa than in the other major regions of the world.

In the developing world, almost 75% of current employment prospects are classified as informal, and SSA is no exception. Working in cities are more costly than those in rural areas. Urban workers must allocate a larger portion of their salary to housing, transportation, and food costs, which fall under the purview of employers. Due to this, employers are less likely to hire people on the basis of merit and more likely to base their judgments on the cost-benefit analysis. The failure of developing countries to collect taxes and other essential domestic resources required for reinvestment is linked to a significant percentage of the working-age population engaging in illicit and informal industries hence a decline in economic growth and development (World Bank, 2017).

African cities may be expanding as a result of a major exodus from rural areas, along with the increasingly destructive effects of climate change. Climate change has been identified as one of the most daunting challenges facing the world in this century and it is particularly more serious in developing countries largely due to their geographic exposure, low incomes, greater reliance on climate-sensitive sectors and weak capacity to adapt to the changing climate (World Bank, 2017).

In fact, the economic landscape of most African countries depends essentially on the dynamics of climate change. In Africa, the vulnerability of the overall economy and key sectors driving economic performance such as agriculture, forestry, energy, tourism, coastal and water resources to climate change have been acknowledged to be substantial (Mendelsohn, 2009)

The geographical location of most African countries on the lower latitudes has already put the region at a disadvantage where about 80 percent of damages from climate change are concentrated (World Bank, 2017).

Any further warming would seriously affect productivity (Mendelsohn, 2009). Yet, Africa contributes a small proportion to the global greenhouse emissions. As articulated by Earth Trends (2009), it is less than 5 percent of total carbon dioxide-equivalent emissions and this share is unlikely to grow substantially in the nearest future. This will change the dynamics of the state of the climate and causes a detrimental impact on agricultural and pastoral activities that rely primarily on the dynamics of climate change. Farmers in rural regions will adopt new behaviors to assure their development if they are unable to adjust to the dangers of climate change, manage climate unpredictability, or build a good capacity for adaptation (survival).

Unfortunately, cities in developing nations, particularly those in Sub-Saharan Africa, have grown into climate change drivers, despite being challenged with urbanisation issues, natural dangers, and their linkages. According to the AfDB *et al*. (2016), the IPCC (2014), and Amraoui et al. (2011), Africa is the most vulnerable continent to climate variability and change, a situation worsened by the combination of "many limitations" such as widespread poverty and a lack of adaptation capability. In fact, hydrological risks such as droughts, floods, and landslides account for more than half of Africa's natural disasters (CRED, 2015).

The temperature variability between 1970 and 2004 was estimated at between 0.2°C and 2°C for the African continent (Amraoui *et al.*, 2011). In comparison to the period 1980-1999, the excess warming for the decade 2020 could range between 0.5 °C and 1.5 °C, and between 1.5 °C and 6 °C for the decade 2090 (GIEC, 2007).

According to Chapman *et al.* (2017), urbanisation diminishes green space and increases impervious surfaces, which reduces evapotranspiration and hence causes a lot of urban heat islands (UHI). Heat from human activities, building climate control, and meteorological conditions all contribute to the growth of urban heat islands (UHs). Still, according to Chapman et al. (2017), the UHI is the clearest example of how land use and land cover change influence local and regional climate, citing writers such as Pielke (2011). As a result, assessing climate change without taking into account urban land use patterns ignores the connection between climate change and the UHI, potentially underestimating future rises in both mean and high urban temperatures.

However, migrant patterns are growing urban populations, resulting in extra needs for which the urban environment is unprepared. As a result, migration has the potential to harm the environment, indicating the existence of a vicious cycle. To say but the least, environmental degradation drives migration, which contributes to environmental degradation in (urban) destinations. Furthermore, Africa's rapid urbanisation presents severe problems for government officials: sanitation, water and energy supply, basic amenities (schools, hospitals, police, and so on), unemployment, insecurity, slum growth, and so on.

In conclusion, the intersection of urbanisation, climate change, and economic growth in Sub-Saharan Africa is a complex and pressing issue. As this region undergoes rapid urbanisation, understanding the interplay between these factors is essential for guiding policies and interventions that promote sustainable development, reduce vulnerability to climate change, and enhance economic opportunities. This research aims to provide evidence from Sub-Saharan Africa to shed light on this critical nexus and inform strategies to navigate the challenges and harness the opportunities presented by these interlinked forces. By doing so, it contributes to the broader global discourse on sustainable development and climate resilience, with implications beyond Sub-Saharan Africa.

**Statement of the Problem**

The effect of climate change and urbanisation on economic growth has been the subject of many discussions and studies in recent times. Due to the fact that urbanisation and climate change play an important role in economic growth and the development of an economy.

The migration of people from rural to urban areas has always been considered as a windfall for various economies that gained from the implied factors of production, in this case labour, in significant quantities and inexpensively. Labour increases the overall productivity of the economy, resulting from the process of structural change. That is especially the case in the reallocation of resources between regions and sectors, of which one of the main dimensions is the transfer of the workforce from agriculture to the industrial sector (Lewis, 1954).

The structure of the economy due to rural exodus, for a long time, has had a positive effect on the rate of urban growth, which represents a factor of wealth creation for the economy (Todaro & Haris, 1970). In conjunction with economic development, the proportion of the urban population in the world has increased from 30% in 1950 to around 50% by 2010 (United Nations, 2007). Today, 54% of the population in the world lives in urban areas and this trend is expected to continue. According to the World Bank (2015), the expected number of people living in cities will rise to six billion by 2045, an increase of two billion urban inhabitants. With over 80% of global GDP will be generated in cities, urbanisation will contribute to the sustainable growth if it is well managed by increasing productivity, enabling innovation and new ideas.

In contrast to the above results, while urban concentration has been beneficial for the economic growth of high-income countries, such effects do not hold for developing countries according to Bala (2009). This view contrasts with authors such as Bertinelli and Strobl (2007), Henderson (2003), particularly those who reported a particularly important effect on the low levels of economic development. Following Frick and Pose (2018), urban concentration reveals totally disconnected from the economic performance of the considered country, in cases of low levels of economic development, especially in Sub-Saharan Africa.

It seems that with a record urbanisation rate of 40% achieved in 2016, the GDP per capita of Sub-Saharan Africa stagnates at around 3,750 current US dollars (World, 2016). Thus, it appears, without extending to all African cities, that the drive mechanism linking urbanisation and economic development has, until now, worked less well in Africa than in the other major regions of the world.

Several studies on urbanisation and growth in the literature mainly focus either on the effects of urbanisation on economic growth. While the majority of studies such as Hossain (2011); Zhao and Wang (2015); Todaro and Haris

(1970); Lewis (1954); Nguyen (2018); Henderson (2003); World Bank (2009) among others, have discovered a favorable association between economic growth and urbanisation. Others such as Turok and McGranahan (2013); Nassori (2017); Frick and Pose (2018) and Bertinelli and Strobl (2007) found no relationship between economic growth and urbanisation. These studies show that urbanisation is one of the most relevant determinants of economic growth in the sub-Saharan countries.

Nonetheless, these studies have produced mixed results. The major weakness in their analyses is the measurements of urbanisation, cross-country units, estimation techniques, and data span. Furthermore, these studies do not explicitly consider the climate context. This could justify the conflicting results of those studies conducted for some of them in a framework that linked only these two variables (Hossain, 2011; Zhao and Wang, 2015; Nguyen, 2018). Climatic change, end up supporting decisions to migrate either internally or overseas (Mbaye et al., 2021). Indeed, one of the mechanisms for dealing with the loss of livelihoods due to climate change is migration out of affected areas (Marchetta, 2021; Rigaud *et al*.,2018).

Climate change rather accelerates the pace of rural-urban migration that causes urbanisation related issues such as settlement issues, pressure on public facilities, outbreak of diseases due to overcrowding, social vices among others leading a decline in economic performance. However, climate change plays a significant role in influencing the urbanisation -economic growth relationship. The question is, do climate change variables such as temperature and precipitation moderate the effect of urbanisation on economic growth?

Climate change have a significant impact on both economic activity and societal reconfiguration (migration, rural exodus, etc.). Climate change is regarded as one of the most pressing challenges confronting the world, with Sub-Saharan Africa bearing the brunt of the burden due to its geographical isolation, low incomes, reliance on climate-sensitive sectors of the economy such as agriculture, and limited capacity to adapt to changing climate (Ayodele ,2012). Climate change is detrimental not only by economic losses such as decreased agricultural production, ecosystem losses such as forestry, erosion, and aquatic life, as well as floods, excessive heat, draughts, and labor losses, but also by increases in morbidity, mortality, and social instabilities. Climate change's indirect effects, such as death and disability, have lasting economic and welfare repercussions.

Countries pay opportunity costs by not investing in research and development and capital investment (e.g., infrastructure) when they expend resources to adapt to climate change, which is a binding limitation to growth and development. However, several studies on climate change and economic growth focus mainly on the effects of climate change on economic growth. Majority of the studies found that climate change has an adverse impact on economic growth (Ali, 2012; Bernauer *et al*., 2010, Dell, Jones, & Fankhauser & Tol, 2005; Olken, 2012 & UNICEF, 2015). The major weakness in their analyses is the measurement of climate change and estimation technique as well as data span. However, these studies failed to notice the fact that temperature and precipitation at a certain level support economic growth especially in SSA where agriculture is the backbone of economic growth. The question is what is the intensity of climate change variables on economic growth in the region?

The volume of precipitation and temperature are commonly used as indicators of climate change in most studies. These isolated pieces of information are rather insufficient to capture such a complex phenomenon as climate change. However, Harari and La Ferrara (2012) employed the standardized precipitation and evapotranspiration index (SPEI), Dai (2011), Couttenier and Soubeyran (2013) used the Drought Meteorological Index (DMI), Palmer (1965) deployed Drought Severity Index (PDSI). Thus, according to the researcher's knowledge, no climate change indicator or index has been created using principal components analysis (PCA). Principal component analysis (PCA) index would be created for the most widely used isolated climate change variables in the literature that is temperature and precipitation. This will help visualize data in lower-dimensional space, making it easier to identify patterns and relationships between data points.

Thus, there is a need to understand the impact of climate change and urbanisation on economic growth in Sub-Saharan Africa and the moderating role of climate change variables in this relationship. Additionally, it is important to explore the non-linear relationships between urbanisation, climate change (temperature and precipitation), and economic growth in the region. Policymakers need to recognize the potential challenges and opportunities posed by urbanisation and climate change, and formulate effective policies to support sustainable economic growth while mitigating climate-related risks.

**Objective of Study**

The general objective of the study is to analyze the effects of urbanisation and climate change on economic growth in Sub-Sahara Africa from 2000 to 2020.

The specific objectives are to:

1. determine whether there is a non-linear effect of urbanisation on economic growth in sub-Saharan Africa.
2. determine whether temperature moderates the effect of urbanisation on economic growth in sub-Saharan Africa.
3. determine whether precipitation moderates the effect of urbanisation on economic growth in sub-Saharan Africa.
4. Investigate the non-linear relationship between climate change and economic growth in sub-Saharan Africa.

**Research Hypothesis**

1. $\boldsymbol{H_0}$: There is no non-linear relationship between Urbanisation and economic growth in sub-Saharan Africa
2. $H_0$: Temperature does not moderate the effects of urbanisation on economic growth in sub-Sahara Africa
3. $H_0$: Precipitation does not moderate the effects of urbanisation on economic growth in sub-Saharan Africa
4. $H_0$: climate change has a linear relationship with economic growth in sub-Saharan Africa.

**Significance of the Study**

The displacement of populations from rural to urban areas (rural exodus) has always been considered as a windfall for various economies that benefit from the implied factors of production, in this case labour, in significant quantities and inexpensively. Labour increases the overall productivity of the economy, resulting from the process of structural change.

That is especially the case in the reallocation of resources between regions and sectors, of which one of the main dimensions is the transfer of the workforce from agriculture to the industrial sector (Lewis, 1954).

For a long time, the structure of the economy in Africa due to rural exodus has had a positive effect on the rate of urban growth, which represents a factor of wealth creation for the economy (Todaro and Haris, 1970). In addendum, this study adds to the existing literature by contributing to the existing debate on the relationship between economic growth, climate change, and urbanisation and advances salient recommendations to aid policy makers.

Africa, and for that matter, Sub-Sahara Africa, is the most vulnerable continent to climate variability and change, a condition that is exacerbated by the interaction of "multiple constraints," including widespread poverty and a weak capacity for adaptation. In effect, over half of Africa's natural disasters are related to hydrological hazards, such as droughts, floods, and landslides (CRED, 2015). This study through policies that would be recommended would help policymakers reduce and mitigate the damaging effect of climate change and its related challenges on growth and hence facilitate economic growth in Sub-Saharan Africa.

It therefore stands to reason that a better understanding of the link between climate change, urbanisation, and economic growth is important for policies to attract the needed climate change and urbanisation policies to the various sectors of the economy in order to propel economic growth. This study's significance lies in its contribution to the understanding of the complex interactions between urbanisation, climate change, and economic growth in Sub-Saharan Africa. The recommendations provided offer valuable guidance to policymakers, while the empirical evidence and methodological insights are valuable for researchers and academia

**The scope of the study**

The study investigates the effect of climate change, urbanisation, and economic growth in Sub-Saharan Africa from 2000 to 2020. The study employed the Dynamic Panel Data Analysis. For robustness testing, the system GMM proposed by Arrelano and Bond (1991) and Bundell and Bond (1995) have been adopted in this study.

The study is limited to sub-Sahara Africa to give a better understanding of the relationship between climate change, urbanisation, and economic growth. The study could not cover all the 48 sub-Saharan countries due to the unavailability of data for some countries. However, we settled on 32 sub-Sahara African countries.

**Limitation of the Study**

The study seeks to estimate the effect of urbanisation and climate change on economic growth in sub-Sahara Africa utilizing annual panel data from 2000 to 2020. However, this study was without some key problems. The major problem encountered during the study was the inaccessibility of data for most sub-Sahara Africa countries. The study concentrated on 32 sub-Sahara African countries out of 48 countries in the region due to missing data point or values. Furthermore, there were no data on some of the variables for some of the countries making it difficult to carry out country specific analysis on the effect of climate change and Urbanisation on economic growth for individual specific countries.

Despite these limitations the results and conclusions drawn from the study are reliable, valid and consistent

**Organisation of the Study**

The study is divided into five chapters with each chapter divided into sections. Chapter One focused on the introductory chapter of the study and outlines the background, problem statement, the purpose and objectives of the study, the hypothesis to be tested, significance, the scope of the study and the limitations of the study. Chapter Two focused on the review of related literature by first looking at the theoretical literature review and then the empirical literature review. Chapter Three presented the methodological framework and techniques used in conducting the study as well as the sources of data collection. Chapter Four reported on the econometric estimation results and discusses in relation to the model specified in chapter three. Finally, Chapter Five the summary, conclusion, policy recommendations and direction for future research.

# CHAPTER TWO

# REVIEW OF RELATED LITERATURE

## Introduction

The objective of this chapter is to present a review of relevant literature about the effect of climate change and urbanisation on economic growth. It is organised into two main sections. The first section presents theoretical literature based on conceptual issues and the theories that explain climate change and growth as well as urbanisation and growth. The second section presents the empirical literature review. It reviews empirical studies on climate change and economic growth, urbanisation and economic growth and climate change and urbanisation.

## Theoretical Literature

According to historical teachings by Bairoch (1988), urbanisation, which is seen as a critical component in a country's growth, has a variety of factors. The term "urbanisation," as defined by the United Nations, refers to a multifaceted dynamism that might come from a shift over time, such as a migration of rural populations to urban regions or from an increase in the urban population that is quicker than the rural population increase (Nassori, 2017). Urbanisation has an impact on both economic growth and environmental quality during its development process. For that purpose, numerous theoretical and often contradictory approaches to analyzing the interplay between these three variables have been provided.

The key sources for the study of the relationship between economic growth and urbanisation are Lewis (1954), Todaro and Harris (1970), and later, Cahuc and Célimène (1993). The analysis of the relationship between economic growth and urbanisation derives mainly from the works of Lewis (1954), Todaro and Harris (1970) and later from those of Cahuc and Célimène (1993) on the theory called Migration Model or the Todaro Model. Although developed to describe the process of economic development in developing countries, the model of the dual economy proposed by Lewis (1954) and formalized by Fei and Ranis (1961) has long dominated the literature on urbanisation. Indeed, Lewis (1954) proposed a theory in which the development of the industrial sector can help developing countries minimize unemployment caused by excess labor in the rural sector. The author claims that labor remains plentiful in the agricultural sector, owing to the relative shortage of land, based on the dual structure of developing countries' economies.

According to Mileva (2007), the Arellano and Bond (1991) difference GMM estimator was first proposed by Holtz-Eakin et al. (1988) and later expanded by Arellano and Bond in 1991. Like in the case of other difference GMM estimators, the Arellano and Bond estimator perform poorly as the exogenous regressors in the model increases. That is, the Arellano and Bond estimator can perform poorly if the autoregressive parameters are too large or the ratio of the variance of the panel-level effect to the variance of idiosyncratic error is too large (STATA Inc., 2009).

An improved version of the Arellano and Bond panel data difference GMM estimator was proposed by Arellano and Bover (1995) and fully developed by Blundell and Bond (1998). Arellano and Bover (1995) construct a panel data GMM estimator in which the regression equations are in levels, and the additional instruments are expressed in lagged differences. Blundell and Bond (1998) augment the original differences GMM estimator with the level-equation estimator to form a system of equations known as "system GMM". The resulting system of regression equations in differences and also levels has better asymptotic and finite sample properties than the Arellano-Bond (1991) differences GMM estimator (Blundell & Bond, 1998). The Blundell and Bond (1998) estimator accommodates exogenous variables by including instrument generated from the exogenous variables.

The System GMM estimator (Blundell-Bond estimator) uses both lagged levels as instruments for contemporaneous first-differences and lagged differences as instruments for contemporaneous levels, whereas the Difference-GMM (Arellano-Bond estimator) estimator uses only lagged levels as instruments for contemporaneous differences.

Hsiao (2003) documents the importance of adopting panel data in analyses. These are presented in Baltagi (2008) and summarised as follows: panel data provides sufficient observations and, subsequently, more sample variability, less collinearity, more degree of freedom and more accurate inference of model parameters.

Again, panel data model better captures the complexity of dynamic behaviors than a single cross sectional or time series data. With panel data models, performance of each variable can be observed over time and more informed judgment can be made. Generalizing with the information obtained from the variable can lead to unbiased estimates. Therefore, by pooling a cross-sectional sample of variables over time, variations in each unit over time are capture.

Baltagi and Levin (1992) posited that panel data model are better able to capture the heterogeneity inherent in each individual variable unit. The structure of panel data suggests that the cross-sectional units whether, individual, firms, states or countries are heterogeneity. In empirical modeling ignoring the heterogeneity effects when in fact they exist leads to biased and inefficient results.

A rural exodus (an increasing factor of urbanisation) can then take place without harming the rural sector's agricultural output potential. Furthermore, Lewis's progress is based on agricultural productivity increases, which leaves a significant amount of labor available for the urban industrial sector to contribute to industrial expansion. The Lewis model predicts that urbanisation has a positive influence on the primary sector, reducing disguised unemployment and reducing wage disparities between sectors. In short, the wage disparity between the traditional and modern sectors is the individual motivation for people to migrate to cities.

Todaro (1969) believes that people travel to cities in order to make more money than those in rural areas, and that the possibility of obtaining work is directly connected to the urban employment rate. In other words, even in the face of significant urban unemployment, a difference in urban-rural income might lead to an increase in the urban population. Cahuc & Célimène (1993), citing Lewis (1954) and Todaro and Harris (1970), conclude that the disagreement between Lewis and Todaro's theories is primarily due to the structural differences between the two economies and that their conclusions are based on returns in the agricultural and industrial sectors.

As a result, Cahuc & Célimène (1993) challenged Todaro's theory also called Todaro Migration Model or the Todaro Model, claiming that job creation would not only increase the rate of urbanisation but also contribute to a spatial extension of the urban labor market. The expansion of the urban labor market, in particular. By lowering the marginal cost of transportation for workers, migration would be boosted, and unemployment would rise.

According to neoclassical theorists (Kuznets, 1955; Henderson, 2003), economic growth is favorably linked to urbanisation in both rich and poor countries. As a result, there is a polarisation of the population at the start of the development process. When development extends throughout the rest of the country, a diffusion process begins. It should also be emphasized that a high rate of industrialisation or significant economic creation has a detrimental impact on the environment in terms of degradation. Aside from the various theoretical methods that have evolved over time, factors that promote population movement are not only numerous but also interrelated. For example, climate change might cause health difficulties or food insecurity, which can lead to population relocation from vulnerable areas to safer areas (Piguet, 2010).

Given that all of the reasons reinforce each other, it is likely hard to determine the "main" source of urban growth in such circumstances. Other theoretical works describe the relationship between climate change, urban settlement, and the impact on wealth creation in urban regions based on these considerations. Models of urban space organization are diverse and varied (Bailly, 1973). According to Bailly (1973), the term "displacement of populations" should be interpreted in its broadest geographical sense to include, in addition to migrations in the strict sense, "movement phenomena" that encompass a wide range of displacements that do not result in a permanent or long-term change of residence.

Thus, for demographers, the foundations of urbanisation may be expressed quite neatly through a quasi-theoretical representation linked to another, that of the demographic transition, which is known to have had a significant impact on demographic thought and research (Allen and Sanglier, 1981). But, beyond these completely contradictory theoretical perspectives on environmental degradation, urbanisation, and economic growth, there is other theoretical research that informs us about the relationship between climate change and economic growth. The natural environment has a dual impact on a country's economic performance: it produces natural resources that are used as direct and indirect inputs in the production of commodities and services.

The natural environment serves as a source of various natural resources such as minerals, timber, water, arable land, and energy sources like oil and gas. These resources are fundamental inputs in the production process of a wide range of commodities and services. For example, minerals extracted from the earth are used in manufacturing industries, agricultural land provides the basis for food production, and energy resources power factories and homes. These natural resources are essential for economic activities and contribute to the production of goods and services.

Natural resources are not just direct inputs into economic activities but also serve as indirect inputs. In addition to the primary use of resources like timber or water in specific industries, they also have spillover effects on various sectors of the economy. For instance, the availability of clean water is not only crucial for agriculture but also for maintaining public health, while forests provide not only timber for construction but also help regulate climate and support biodiversity.

Natural resources are directly extracted, processed, and utilized in various economic sectors. The extraction and trade of these resources contribute to a country's economic output and export revenues, which can boost economic growth and development.

The natural environment provides ecosystem services that are essential for the functioning of the broader economy. These include clean air and water, pollination of crops by insects, climate regulation, and support for biodiversity. These ecosystem services are integral to maintaining the overall health and productivity of the economy.

The environment is responsible for man's complete life, including fundamental food, air, water, temperature, plants, soil, and animals, among other things. The environment has shaped and conditioned man's experience throughout time and space, from the most primitive stone age living to the most sophisticated modern life with computers and jets. At the same time, the environment serves as a landfill for all trash produced by human activity. As a result, it is unquestionably true that the environment is man and that man is the environment. Without any external disruption, the environment maintains a delicate equilibrium in which each organism contributes to the greater good.

The pursuit of growth and uncontrolled consumption, on the other hand, has thrown the ecological balance off over time. Many climate scientists and economists have devoted a significant amount of time and effort to analyzing this disequilibrium in order to restore equilibrium.

The mechanisms of transmission from climate change to economic growth are identified by Fankhauser and Tol (2005). They identify capital accumulation and savings as the primary dynamic channels through which climate change may affect long-run growth, using a typical neo-classical growth theory as the core framework of inquiry. Because saving and thus investment constitute the present value of future consumption, climate change will have an impact on future consumption and household welfare. The rate of human capital accumulation is another potential transmission channel. Temperature rises slow the rate of learning and have a negative influence on the health of the workforce. The net result is a decrease in labor productivity and long-term economic growth (Fankhauser & Tol, 2005).

Milliner and Dietz (2011) looked at the hypothesized mechanisms through which climate change could affect long-term economic growth. They argue that the distinction between adaptation and growth, on the one hand, and mitigation and development, on the other, is a muddled one. Milliner and Dietz (2011) come to the critical conclusion that allocating investment between productive capital and adaptive capital is a difficult issue.

This conclusion implies that as an economy develops over time, it will protect itself from the dangers of climate change. For example, economic growth will result in less reliance on climate-sensitive sectors like agriculture. The correlation might theoretically be established using macroeconomic and microeconomic variables. The two areas that are most stressed on the macroeconomic side are the drive on production levels, such as agricultural yields, and the economy's ability to grow (for example, by changing investments or institutions that influence productivity growth). The correlation includes a variety of characteristics from the microeconomic analysis level, such as physical and cognitive labor productivity, conflict, and health, all of which could have economy-wide effects (IPCC, 2007; Gallup, 1999).

Increased temperature, for example, might lead to political instability, which can stifle factor accumulation and productivity growth Several theories have been constructed from various disciplines to provide insight into the complex drivers of urbanisation: economics, geography, politics, and so on. While one group of theories considers the family as the primary unit in the migration decision-making process, another set of models, referred to as "choice-centred models," considers the individual. Household allocation models, agent-based models, and more ad hoc models are all used to anticipate migration decisions made by households, individuals, or through the dynamic interplay of multiple actors in origin locations. Due to the larger reliance of rural subsistence on the climate, the relationship between climate change and rural subsistence is believed to be substantial.

The decision to migrate and the migration destination are two components of the migration process. Individuals make migratory decisions depending on a collection of "push" and "pull" variables, according to choose-centered models. Political persecution, violent conflict, violations of human rights, governmental failure, climatic change, economic hardship, and economic discrimination against certain ethnic groups are likely to exacerbate out-migration flows (Neumayer, 2005). Economic conditions, job prospects, the rule of law, democracy, and the availability of social services (education and health care, ) in destination regions are all common pull factors

Gravity theories are helpful in determining migration trends. They are founded on Newton's law, which states that the interaction between two points is determined by "bodies" and "masses." One of the most recent applications of the gravity model in the assessment of migratory movements in African coastal areas is by the World Bank (2018) (Sherbinin, 2021). It assumes that distance, geography, and political restrictions determine mobility between two sites. One of the major drawbacks of this method is that it ignores individual migration motivations. Amid household allocation theories, migration occurs as a result of a household`s labor portfolio diversification strategy in uncertain circumstances, rather than as a result of individuals` free will. Households manage their members` distribution between urban and rural areas in order to maximize present income and reduce climatic risk.

It is believed that the household in question lives in a rural location that is located beyond commuting distance from a nearby urban center. When compared to other models, Agent-based Models (ABM) are claimed to perform better (Suleimenova et al., 2017). ABM is concerned with simulating migration dynamics in order to overcome the constraints of observational assessments of climate-induced migration (Entwisle et al., 2016). The multi-agent model, as presented by Napoletano (2017), is a paradigm for evaluating a dynamic economy made up of heterogeneous agents that interact with one another. One of the unique features of the ABM model is that it does not rely on the economic agent's perfect rationality.

The dynamic method through which the climate-migration relationship might function is described by agent-based models (ABM). Individuals, land parcels, villages, families, and social networks are all considered in ABM, as are their dynamic relationships. ABM is dynamic; unlike regression, it accounts for interactivity between individuals, demographic changes, and adaptation over time. Households are the model's primary points of integration because they are made up of people, are integrated into villages and social networks, and control land parcels (Napoletano,2017).

Households can own or rent land, which they can pass on to others when they die or for any other reason. When family members marry and start their own households, the composition of the family can vary. Households also own land and other assets, and thus play a key role in the community's development and maintenance of networks and ties with the rich. Gender, age, and marital status are all crucial qualities that each member of the household possesses. Death, marriage, procreation, and migration are all examples of demographic, social, and economic changes that affect individuals (Napoletano, 2017).

Land parcels also include characteristics such as flooding vulnerability, distance from the village, size, and soil suitability for various agricultural applications. Villages have characteristics such as being made up of people, houses, and land parcels, as well as population size, migratory patterns, and social networks (connectivity). Climate change and migration have a distinct relationship in ABM: rainfall affects crops, crops affect income, income affects assets, and assets affect migration.

**Climate Change and Economic Growth**

The potential effects of precipitation and temperature on economic activity are well covered in the literature. Both theoretical and empirical data support the negative impact of changes in precipitation and temperature on the growth rate of GDP. First, the destruction of endangered species, the loss of people due to harsh weather, and ecological loss from erosion, floods, and drought all have a long-term negative impact on economic growth (Pindyck, 2011). The resources needed to mitigate the effects of climate change would limit investment in human capital, research and development, and physical and economic infrastructure, which would slow growth (Ali, 2012 & Pindyck, 2011). What does the literature have to say about the empirical relationship between climate change variables (temperature and precipitation) and economic growth?

Dell *et al.* (2008) examined the effects of climate change on economic activity using annual data on temperature and precipitation variations over a 50-year period at the global level. Their research yielded three main conclusions. To begin with, rising temperatures have a considerable negative impact on economic growth in poor countries, while this effect is negligible in developed countries. Second, greater temperatures in poor countries appear to reduce growth rates rather than just output levels. Third, rising temperatures have far-reaching consequences for poor countries, lowering agricultural, industrial, and aggregate investment, as well as increasing political instability.

According to Dell *et al*. (2008), the aggregate effect of climate change is dependent on a country's degree of development, with the negative effect diminishing as the country progresses up the development ladder. This conclusion is consistent with Milliner and Dietz (2011)'s theoretical conclusion that economic development will automatically insulate countries from the perils of climate change, and thus a separate adaptation investment from productive capital accumulation may not make a significant difference. In terms of precipitation, Dell *et al.* (2008) found that it had little impact on economic growth. This conclusion holds regardless of a country's development level. A rise in growing temperatures has the potential to have a considerable impact on agricultural output, farm income, and food security.

The effect of temperature varies depending on whether you're in a temperate or tropical environment. Crop suitability and production are expected to rise and extend northwards in mid and high latitudes, while the opposite is predicted for most tropical countries (Gornall *et al*., 2010). The studies discovered that a 2°C increase in temperature in the mid and high latitudes might improve wheat yield by 10%, but it would decrease by the same amount in the low latitudes. Taking technology into account, the studies concluded that those rising temperatures in Russia's Federation might raise wheat productivity by 37 to 101 percent by the 2050s.

According to Mendelsohn (2009) the impacts of climate change may have been exaggerated in both theoretical and empirical literature, and climate change will likely pose less of a threat on a global scale in the next half-century or so than is now expected. Warmer temperatures, according to Mendelsohn (2009) extrapolated to 2100, will have yearly net market impacts of between 0.1 and 0.5 percent of GDP estimates much too low to have any immediate impact. As a result, it stands to reason that unrestrained action could be more harmful than the imagined threat posed by climate change.

Dell *et al*. (2012) uses historical fluctuations in temperature within countries to identify its effects on aggregate economic outcomes. The study revealed three primary results. First, higher temperatures substantially reduce economic growth in poor countries. Second, higher temperatures may reduce growth rates, not just the level of output. Third, higher temperatures have wide-ranging effects, reducing agricultural output, industrial output, and political stability. These findings inform debates over climate’s role in economic development and suggest the possibility of substantial negative impacts of higher temperatures on poor countries.

Dell *et al.* (2009), in a related study, integrated theory and empirical evidence to investigate the temperature-income relationship further. Dell et al. (2009) finds negative cross-sectional inter- and intra-country associations between temperature and income using data from 12 countries in the Americas. However, as the authors explain, long-run adaptation mitigates around half of the unfavorable short-run impacts of temperature on growth.

Nordhaus (2006) developed crucial empirical conclusions about the effect of geography on economic success (economic growth). Nordhaus (2006) looked into three G-Econ data base applications and came up with some intriguing results. The data first revealed a climate-output reversal. The link between temperature (a proxy for climate change) and output per capita was shown to be negative by Nordhaus (2006), whereas the association between temperature and output per area was found to be considerably positive (country size-adjusted GDP). Nordhaus also discovered that geographical factors account for a large portion of the income disparities between Africa and the rest of the globe. The G-Econ data source gave a more accurate estimate of the economic impact of greenhouse warming than earlier research had suggested.

Deschenes and Greenstone (2007) estimate the effect of random year-to-year variations in temperature and precipitation on agricultural profit to determine the economic impact of climate change on US agricultural land. The researchers employed a county-level panel data file derived from the Census of Agriculture to estimate the impact of weather on agricultural earnings, conditional on county and state by year fixed effects.

The preferred estimates, based on long-run climate change predictions from the Hadley 2 Model, showed that climate change will result in a $1.3

billion ($2002) increase in yearly agricultural sector revenues, or a 4.0 percent rise. Large negative or positive effects are unlikely because the 95 percent confidence interval runs from-$0.5 billion to $3.1 billion. The basic finding of a statistically small effect is robust to a variety of specification checks, including adjusting for the large number of available controls; modeling temperature and precipitation flexibly; estimating separate regression equations for each state; and implementing a procedure that minimizes the impact of outliers.

Despite the fact that the total effect is minimal, we found significant variation in the expected effects among states. Furthermore, the study showed that expected temperature and precipitation increases will have almost no effect on yields among the most significant commodities (corn for grain and soybeans), implying that the small effect on profits is not attributable to a short-term price increase.

Bonds et al. (2010) and Strulik (2008) make theoretical predictions with little evidence to back them up. Children's cognitive and physical growth is impaired by diseases associated with the climate, such as malaria and diarrhea. As a result, they experience later-life poverty and have few resources to shield their own children from these diseases. Furthermore, a high infant death rate may encourage parents to have multiple children, spreading out their financial commitment to schooling and healthcare. Thus, more individuals would become impoverished if infant and child mortality and morbidity increased as a result of climate change and hence slow down economic performance. The tropics and subtropics are the areas with the most poverty. Because of this, some experts such as Bonds et al. (2010) and Strulik (2008) have come to the conclusion that one of the causes of poverty is a tropical climate.

While Masters and McMillan (2001) concentrate on climate, agricultural pests, and poverty, Gallup, Sachs & Mellinger (1999) highlight the connection between disease, poverty, and the environment. Other studies (Acemoglu, Johnson & Robinson, 2001, 2002; Easterly & Levine, 2003) contend that if differences in human institutions (the rule of law, education, etc.) are taken into consideration, the influence of climate on development vanishes.

Van der Vliert (2008), however, illustrates that climate impacts human culture and consequently institutions, but this area has not yet been covered in the literature on economic growth. In a single-equilibrium model, Bloom, Canning, and Sevilla (2003) find only weak evidence for the impact of climate change on past growth, but strong evidence in a multiple-equilibrium model: hot and wet conditions and high rainfall variability lower long-term growth in poor countries (but not in hot ones) and raise the likelihood of being poor.

Dell *et al.* (2014) employed panel methods to examine how temperature, precipitation, and windstorms influence economic outcomes. The study concentrated on changes in weather realizations through time within a certain spatial area and show effects on, among other things, economic growth, labor productivity, energy demand, health, and conflict. These studies aid in genuinely identifying the breadth of channels linking weather and the economy; varied treatment effects across different types of locales; and nonlinear impacts of weather variables by utilizing exogenous variation over time within a specific spatial unit. Two goals were paramount in the study. First, the study provides a summary of recent research, outlining its techniques, datasets, and conclusions. Second, the study takes into account how the new literature might be applied, including new understandings of the "damage function" in models that aim to evaluate potential economic repercussions. Using an autoregressive distributed lag model for panel data, the study finds evidence of both short- and long-run relationships between temperature and per capita income growth. However, the impact of rainfall on growth has little support from the data.

The important lesson of Lanzafame (2012) is that African countries have not adapted well to weather shocks, and without proper intervention mechanisms to arrest the alarming effects of climate change growth may be hampered. The effects of a range of economic effects generated by climate change are assessed using an integrated assessment model (ENVISAGE), which includes a CGE-based economic module and a climate module. Sea level rise, crop yield changes, water availability, human health, tourism, and energy demand are all examples of these impacts.

Two scenarios were compared: a baseline growth path that ignores the effects of climate change and a counterfactual situation that includes the effects of climate change. model and evaluates the overall magnitude of the impacts, their regional distribution, and the contribution of each individual impact to overall income and welfare variation. The findings (e.g., on real GDP) suggest that climate change has a significant impact on economic growth, particularly in developing nations and over time, especially Africa. The Fourth Assessment Report of the IPCC sheds some light on how climate change will affect the development of Africa. For instance, yields in some nations could be reduced by as much as 50% by 2020, and crop net earnings could decrease by as much as 90% by 2100, with small-farm owners suffering the most.

Additionally, it would exacerbate the water stress that some nations are now experiencing approximately 25% of Africans, or roughly 200 million people, currently experience high water stress. By 2050, 350–600 million people in Africa are anticipated to be at greater risk of greater water stress, and 25–40% of the mammal species found in national parks in sub-Saharan Africa may go extinct (Boko *et al.*, 2007).

Alagidede (2014) also contributed to the empirical study of climate change and its impact on Sub-Saharan African economic growth. The study assesses the short- and long-run effects of climate change on growth using data on two climate variables, temperature and precipitation, and panel cointegration techniques. The findings revealed that rising temperatures have a considerable negative impact on economic performance in Sub-Saharan Africa. Furthermore, the results also shows that the link between real GDP per capita on the one hand and climate variables on the other is non-linear.

Climate change and economic growth in Africa were studied empirically by Odusola and Abidoye (2012). They discovered a detrimental impact of climate change on African economic growth by using annual data from 34 countries spanning the years 1961 to 2009. According to their findings, a 1-degree Celsius increase in temperature decreases economic growth by 0.27 percentage points. They found that climate change had a higher negative impact on growth when they looked at a sub-sample in the time dimension from 1961 to 2000. In Africa, growth slows by 0.41 percentage points as the temperature rises by 1 degree Celsius. This study is a contribution to the empirics of climate change and its effect on sustainable economic growth in Sub-Saharan Africa using data on two climate variables, temperature and precipitation, and employing panel cointegration techniques.

Henderson (2014) forecast the short- and long-run effects of climate change on economic growth. The study revealed that an increase in temperature significantly reduces economic performance in Sub-Saharan Africa. Furthermore, the study also concluded that the relationship between real gross domestic product per capita on the one hand, and the climate factors on the other, is intrinsically non-linear.

Barrios *et al.* (2008) found that Sub-Saharan Africa is more severely affected by rising temperatures than other emerging nations. They note that the agricultural output gap between Sub-Saharan Africa and other emerging nations at the end of the twentieth century would have been just 32% of the current deficit if the meteorological conditions (rainfall and temperatures) had maintained at their pre-1960s level. According to an econometric examination of Nigeria between 1980 and 2005, changes in temperature had a negative impact on agricultural output whereas changes in rainfall had a favorable impact (Ayinde *et al.*, 2011). A higher growth temperature can have a substantial impact on farm income, food security, and agricultural output. Tropical and temperate regions experience the influence differently. Crop suitability and productivity are expected to rise and spread northward in mid- and high latitudes, but the majority of tropical countries are experiencing the opposite (Gornall *et al*., 2010). They discovered that a 2°C increase in temperature might improve wheat yield by roughly 10% in mid-and high-latitude regions while decreasing it by the same percentage in low-latitude areas.

According to Gornall *et al.* (2010), rising temperatures in the Russian Federation might result in an increase in wheat output of between 37 and 101 percent. They note that the influence of climate change on economic growth is not substantial using worldwide data from 1950 to 2004. The moving average-based temperature estimate for Africa, however, is related with adverse consequences, albeit at a 10% level.

In addition, Ali (2012) demonstrates that variations in rainfall size and variability have long-term drag effects on the level of output and have a negative impact on growth in SSA. Tol (2018) conducts an assessment of the literature on climate change's influence on the economy and human wellbeing. They came to the conclusion that, in the short to medium term, climate change could benefit people who rely on rain-fed agriculture (since carbon dioxide fertilization makes plants more drought-resistant) and those who spend a lot of money on heating (as warming is faster in winter). However, the negative effects of climate change are expected to outweigh the good ones in the long run. In poorer, hotter, and lower-lying countries, especially in sub-Saharan Africa, the negative effects will be far higher. Development is a supplementary strategy to GHG emission reduction because poverty creates climate change vulnerability. Any trade-off between slower economic growth and lower emissions must be carefully considered.

Climate change may also alter the economy's growth rate and trap more people in poverty, though estimates of the magnitude of these consequences range from negligible to substantial. The negative effects of climate change on growth are well-established in the literature, particularly for SSA economies: warmer temperatures and falling precipitation reduce the capacity to use irrigation to grow crops, as well as to support export-based agriculture and light industry, especially since agriculture is seen as the backbone of most SSA economies' economic growth. Not to mention the floods and drought that destroyed farms and killed people. This has a feedback loop on economic growth and poverty alleviation. However, the debate appears to be one-sided thus far. The magnitude of the influence of climate change on economic growth has not been consistent. As a result, it is necessary to investigate the extent to which climate influences economic activity.

**Urbanisation and Economic Growth**

Numerous previous studies have found a strong relationship between urbanisation and per capita GDP (Henderson, 2003). People frequently accept that economic growth encourages the expansion of modern industry and the growth of the urban population, and that urbanisation fosters economic growth as well. Positive urbanisation policies, with the goal of boosting economic growth, are common in emerging countries (Friedmann, 2006). Today, in the age of globalization, the globe is changing rapidly in terms of urbanisation, with the rate of change in the last three decades being faster than ever before. Simultaneously, the focus of urbanisation has shifted from developed to developing countries.

Many international organizations have backed the concept that urbanisation promotes growth and development and should be fostered in recent decades. According to the World Bank (2009), "There has never been a country that has turned into a middle-income country without first becoming industrialized and urbanized." There has never been a country that has developed into a high-income country without thriving cities. The rush to create countries' cities appears chaotic, yet it is vital (Robinson & Swilling, 2012). The city has the potential to innovate, produce wealth, improve the quality of life, and accommodate more people in a smaller area through agglomeration, while also using more resources and emitting more per capita than any other settlement arrangement.

According to Bertinelli and Black (2004), urbanisation affects economic growth through a variety of mechanisms. To begin with, cities play an essential role in the economic and social structures of both developed and developing countries by providing opportunities for individuals to access educational, job, and health facilities. The ability of a country to develop new technologies and embrace old ones is determined by its educational capital (Aghion and Howitt, 2009). Second, urbanisation entails the agglomeration of people and businesses, which lowers production costs. Urbanisation allows economies to gain competitive advantages on a global scale, cut transaction costs, and allow firms to specialize inside, lowering production costs (Fujita *et al.*, 1999; Krugman, 1991; Kumar & Kober, 2012).

Finally, urbanisation is a significant business element (Glaeser et al., 2010). The concentration of people and businesses in cities makes it easier to obtain financing, promote business ideas, and do business in a larger local market (an urban market with a higher density of consumers).

According to Loughran and Schultz (2005), geography has an impact on a company's performance: when other parameters remain constant, urban businesses are more lucrative than rural businesses. This distinction makes metropolitan regions more appealing to entrepreneurs and businesses. Furthermore, a city's prosperity and growth are significantly reliant on its capacity to attract employees to manufacturing sectors, assign appropriate positions to workers, and continue to develop their abilities (Bacolod et al., 2010). Since its inception, the necessity of skills has been emphasized in the urban economy. The migration of highly qualified people and talents to the big cities is a result of urbanisation. Interactions and spillovers of knowledge and skills occur as a result of this concentration.

Growth and regional agglomeration are "mutually self-reinforcing processes," according to Martin and Ottaviano (1999). Given localized spillovers, "spatial agglomeration is favorable to growth," according to Baldwin and Martin (2004). According to Williamson (1965), the agglomeration is the most essential in the early phases of development. When transportation and communications infrastructure are scarce and capital market reach is limited, the effect of concentrating production in one area can be significantly enhanced.

However, when infrastructure is improved and markets are expanded, congestion externalities may support a more dispersed economic geographical area. Bertinelli and Black figured out urbanisation and development tendencies, and this configuration fits them (2004). Growth is attributed to agglomerated regions ("cities") in such a pattern, as human capital accumulation is thought to occur solely there. These agglomerations' dynamic benefits must be balanced against the expense of static congestion diseconomies. Through the phases of development, the relative importance of these two effects shifts. The potential benefits of human capital accumulation are particularly substantial in the early phases of development, when static congestion diseconomies have little influence. Nevertheless, as the degree of growth increases, the relative importance of static congestion diseconomies will increase. It is stated that urbanisation has recently encountered numerous problems in terms of encouraging economic growth.

Fay and Opal (2000) documented what they called late-twentieth-century urbanisation without growth in underdeveloped countries. It is especially counter to their notion that urbanisation occurs in tandem with economic expansion; the experience of emerging countries over the last several decades is an outlier.

According to Bloom *et al.* (2008), there is no evidence that urbanisation has an impact on economic growth. The need for re-testing the relationship between urbanisation and economic growth, as well as deeply re-considering popular notions and practices of urbanisation expanding dramatically in emerging nations, is emphasized in this study. According to Glaeser (2013), near the bottom of the income distribution ladder, there is a condition of "urbanisation of poor countries." According to Jedwab and Vollrath (2015), large cities are more likely to be found in poorer countries.

Hossain (2011), as well as Zhao and Wang (2015), discovered a favorable association between economic growth and urbanisation. Indeed, Hossain (2011) used panel data from 1971 to 2007 to examine the dynamic influence of economic growth, trade liberalization, and urbanisation in newly industrialized countries. The causality test revealed no long-term relationship, but a short-term unidirectional link between economic growth and trade opening, as well as between urbanisation and economic growth, was discovered. Using a VEC model, Zhao and Wang (2015) discovered that economic growth and urbanisation are positively connected throughout the period 1980–2012. However, unlike Hossain (2011), the findings of the two authors indicate a one-way relationship between economic growth and urbanisation. Urbanisation and economic growth studies are motivated by the rapid growth of the urban population.

According to Nakamura (1985), in Japan, doubling the urban population would result in a 3.4 percent increase in productivity. Ciccone and Hall (1996) show that population density has a positive impact on production in the United States, estimating that doubling the urban population would raise output by 6%. According to Ciccone (2002), doubling the urban population would increase output by 4.5 percent in France, Germany, Italy, Spain, and England. According to Rosenthal and Strange (2004), doubling the size of a city can result in a 3% to 8% boost in productivity in various industries.

Nguyen (2014) investigates the relationship between urbanisation and economic growth in ASEAN nations between 1993 and 2014. The Granger causality test was utilized, as well as the regression estimation method with static and dynamic panel data (Driscoll and Kraay, D-GMM, PMG). Brunei, Cambodia, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam are among the ASEAN nations represented in the sample. The findings indicate that there is at least a causal association between urbanisation and economic growth. And the findings demonstrate that urbanisation has a beneficial impact on economic growth. The relationship between urbanisation and economic growth, on the other hand, is non-linear. After a certain level of urbanisation, economic growth may be hampered. The predicted threshold for the static model is 69.99% and for the dynamic model is 67.94%.

Lewis (2014) studied the relationship between urbanisation and economic growth in Indonesia. In this study, he used time series data from 1960 to 2009 and panel data for regions in Indonesia. The results suggest that urbanisation is positively associated with economic growth, but the rate of change of urbanisation negatively impacts economic growth. Dynamic panel regression estimates provide further evidence of the relative level and magnitude of adverse and negative effects. The results of the panel estimate also imply that the diseconomy effects of urban population growth are linked to insufficient spending on local public infrastructure. Regional governments need to invest more in infrastructure to better cope with the apparent negative effects of rapid urbanisation on economic growth.

Urbanisation, according to Zhao and Wang (2015), is the result of economic growth. The expansion of the industrial sector, which mobilizes a great mass of labour from the rural to the urban environment, is accompanied by the generation of wealth. For example, Arouri *et al.* (2014) and Nguyen (2018), for example, suggested a non-linear relationship. According to Nguyen (2018), urbanisation has reached a point where it can hinder economic growth. This threshold is predicted to be 67.94 percent, implying that when Asian countries' urbanisation rates exceed 67.94 percent, production factors become harmful by producing less wealth.

Leitao (2013) studied the relationship between urban accumulation and economic growth in Europe, the USA, Japan, New Zealand, and Mexico from 1990 to 2008. The results show that urban accumulation promotes economic growth. A 1% increase in urban accumulation, for example, resulted in a 3.19% increase in per capita GDP. Ponc De Leon Barido & Marshall (2014) investigated empirically how national-level CO2 emissions are affected by urbanisation and environmental policy. The study used statistical modeling to explore panel data on annual CO2 emissions from 80 countries for the period

1983–2005. Random-and fixed-effects models indicate that, on the global average, the urbanisation-emission elasticity value is 0.95.

Several regions display a statistically significant positive elasticity for fixed- and random-effects models: lower-income Europe, India and the Sub-Continent, Latin America, and Africa. Using two proxies for environmental policy and outcomes (ratification status for the Kyoto Protocol; and the Yale Environmental Performance Index), the study finds that in countries with stronger environmental policy and outcomes, urbanisation has a more beneficial (or, less negative) impact on emissions. Specifically, elasticity values are -1.1 (0.21) for higher-income (lower-income) countries with strong environmental policies, versus 0.65 (1.3) for higher-income (lower-income) countries with weak environmental policies. Their finding that the urbanisation-emissions elasticity may depend on the strength of a country's environmental policy, not just marginal increases in income, is in contrast to the idea of universal urban scaling laws that can ignore local context.

Most global population growth in the coming decades is expected to occur in urban areas of lower-income countries, which underscores the importance of these findings.

The study of urbanisation has, in recent years, gained increasing importance in developing countries, not only because these countries are in the process of facing rapid urbanisation, but also because the process of urbanisation has been recognized as part of a larger process of economic development that is affecting developing countries. There are two-sided relationships between urbanisation and economic development. On the one hand, it promotes economic development, while on the other hand, it is an impediment to the economic development of most nations.

Shabu (2010) correlated urbanisation with economic development indicators of developing countries and concluded that there is a weak relationship between urbanisation and economic development in developing countries. The study also compared the economic situations of urban and rural areas, which shows that it was better in the cities.

According to Fay and Opal (2000), the majority of African countries are undergoing a phase of urbanisation without economic growth. The factors of urbanisation in Africa, according to these scholars, are not those expected by the theories such as Centre choice theory, gravity model and the ABM model but those originating from the development of the industrial sector. Growth in income, ethnic tensions, civil unrest, democracy, the income gap, and other factors all contribute to Africa's urbanisation style. The majority of these people are migrating to the informal sector in cities, which does not contribute to economic growth. As a result, at the national level, there is a substantial "sterile" urban rise in wealth generation.

Jedwab and Vollrath (2015) use historical data at both the country level and city level in five African centuries between 1500-2010 to revisit the topic of "urbanisation without growth" (Fay & Opal, 2000). In particular, the study first established that, although urbanisation and income remain highly correlated within any given year, urbanisation is 25–30 percentage points higher in 2010 than in 1500 at every level of income per capita. Second, while historically, this shift in urbanisation rates was more visible at the upper end of the income distribution, i.e. in richer countries, it is now partially visible at the lower end, i.e. in poorer countries. Third, these patterns suggest that different factors may have explained the shift in different periods of time. The study used the discussion of these factors as an opportunity to provide a survey of the literature and summarize our knowledge of what drives the urbanisation process over time.

Arouri *et al.* (2014) used dynamic panel data regressions to estimate the effect of urbanisation on human capital and per capita GDP of African countries. The result is an inverted U-shape relationship between the urban population share and per capita GDP. Urbanisation also shows impacts on human capital variables, such as enrollment rates and health variables. Africa's human capital is fostered by these impacts, which are permitting greater and faster growth. The findings also indicated that urbanisation is reshaping the sectoral composition of the economy: services account for 51% of GDP in the most urbanized economies, and agriculture for 76.1% of total employment in the least urbanized countries. The study's empirical findings suggest several policy implications. Sub-Saharan Africa now has inadequate planning systems, planning laws and building standards, bureaucratized and inefficient land policy, and a shortage of qualified and active planners. Urban policies need to be revised in depth to foster human capital. At least five topics should be considered: training and education for urban decision makers; location management and subsidies; development of secondary towns; data for urbanisation management; and management of the informal economy.

Haryanto *et al.* (2021) analyze the causality between GDP per capita, urbanisation, and education. They also aimed to determine the long-term and short-term relationships between economic urbanisation, education, and GDP per capita by applying the Vector Error Correction Model (VECM). Data was obtained from the World Bank and UNDP from 1990 to 2018. According to the estimation results, economic growth and education on urbanisation have the strongest causality in VECM., They are pull factors with a significant effect in the long and short term. Some suggestions concerning policy implications were made, and they include: forming area-based urbanisation, where cities within one area are integrated, to get the impact of an agglomeration economy. Also, the government needs to accelerate the distribution of infrastructure and public facilities in various regions to avoid population density in one area due to urbanisation, and the government needs to pay attention to easier access to education and more equitable ones in various regions. On the contrary, after education is evenly distributed in all regions, the government needs to pay attention to transportation access and infrastructure. There is an emerging consensus that urbanisation is critically important to international development, but there is considerable confusion over what urbanisation actually is; whether it is accelerating or slowing; whether it should be encouraged or discouraged; and, more generally, what the responses should be (Haryanto et al.,2021)

McGrahan & Satterthwaite (2014) review some key conceptual issues and summarize urbanisation trends. It ends with a brief review of urbanisation and sustainable development, concluding that although urbanisation brings serious challenges, attempts to inhibit it through exclusionary policies are likely to be economically, socially, and environmentally damaging. Moreover, with the right support, urbanisation can become an important element of sustainable development.

**Climate Change and urbanisation**

The climate in Africa has always been extremely diverse and unpredictable. It stretches from the arid Sahara to Central Africa's tropical tropics. Long droughts have followed protracted wet periods in locations like the West African Sahel. The intertropical convergence zone, seasonal monsoons in East and West Africa, and the multi-year El Nino/La Nina Southern Oscillation which causes changes in Pacific Ocean temperatures with an indirect effect on African weather, shapes the climate of Sub-Saharan Africa (Conway, 2009).

Climatic change, coupled with violence such as human rights abuse, genocide, politicide, end up supporting decisions to migrate either internally or overseas (Mbaye et al., 2021). Indeed, one of the mechanisms for dealing with the loss of livelihoods due to climate change is migration out of affected areas (Marchetta, 2021; Rigaud et al.,2018).

According to UNHCR (2021), each year, about 20 million people leave their homes to different areas of their country and more migrate internationally due to natural disasters such as prolonged droughts, abnormal heavy rains or rising sea levels, and cyclones. That is the specific case of Madagascar that went through its fifth cyclone, on 22 February 2022, in six weeks. The heavy rain and destructive wind blowing into Madagascar from the Indian Ocean led to the displacement of several populations over six regions (UNHCR, 2021). On a continental level, over the period 2000-2017, major migration hubs were Abidjan in Côte d'Ivoire, Johannesburg in South Africa, and Nairobi in Kenya; whereas in the greater Eastern Africa, migration trends indicated that South Africa absorbed the largest number of migrants (2.4 million) followed by the

Democratic Republic of the Congo (447,000) and Zimbabwe (361,000), as reported by Mpandeli et al. (2020).

But globally, climate change rather accelerates the pace of rural-urban migration (Mukhopadhyay and Revi, 2009).

In a comparable country-level panel study, Naudé (2010) finds no evidence of a direct influence of environmental variables, however Barrios Bertinelli and Strobl (2006) estimate a 0.45 percent rise in urban share with a 1% reduction in rainfall. Despite evidence that the duration of the growing season, for example, changes greatly over much of Africa (Vrieling, de Beurs, and Brown 2011; Vrieling, de Leeuw, and Said 2013), year-to-year climatic variability has received far less attention in such models. For example, increasing environmentally driven income levels as measured by per capita GDP might be more relevant than variability in migration decisions (Marchiori, Maystadt, & Schumacher, 2013).

However, others also have diverse views of the relationship between climate and urbanisation. To investigate the possible effects of urban growth and climate change, Kahn (2009) used county level data from the year 2000 Census of Population and Housing in the United State of America to estimate some simple hedonic home price regressions. The findings indicate that between 1950 and the year 2030, the share of the world's population that lives in cities is predicted to grow from 30% to 60%. This urbanisation has consequences for the likelihood of climate change and for the social costs that climate change will impose on the world's quality of life and hence negatively affects economic growth.

The study also examines how urbanisation affects greenhouse gas production and how urbanites in the developed and developing world will adapt to the challenges posed by climate change. The study find that urbanisation is very significant in determining the gas production in the urban cities.

Deichmann and Bank (2013) examined the significant impact of variations in climatic conditions on urbanisation in sub-Saharan Africa, especially in arid countries. Greater moisture availability retards the growth of nearby cities, while drier conditions accelerate it. This local impact is stronger than the effect on national primate cities. There is also evidence of a shift to non-farm activities during tough times, and women are more likely to drop out of the labor force. Finally, climatic conditions also affect city incomes in countries with high agricultural dependence, presumably through spending on urban goods and services by farmers benefiting from productivity increases. Overall, these findings confirm a strong link between climate and urbanisation. Climate change's predicted negative effects on agriculture will accelerate the growth of African cities that have struggled to absorb a growing population into productive jobs.

Henderson (2014) documents the substantial impact of climate variation on urbanisation in sub-Saharan Africa. In a panel of over 350 subnational regions, the study concluded that drier conditions increase urbanisation in places most likely to have an urban industrial base. Total city income in such places also increases. When receiving cities have an export sector that is not wholly dependent upon local agriculture, migration to cities provides an "escape" from negative agricultural moisture shocks. However, in most places (75% of sample) without an industrial base, there is no escape into alternative export-based employment. Drying causes reduced urban and rural incomes, with little overall impact on the urban population share. Finally, the study also shows that climate variation also induces employment changes within the rural sector itself. Drier conditions induce a shift out of farm activities, especially for women, into non-farm activities, and especially out of the measured work force. Overall, these findings imply a strong link between climate and urbanisation in Africa.

Dia, (2021) sought to analyze the interactions between climate variability, urbanisation, and economic growth in Sub-Saharan Africa. Specifically, it analyzed the extent to which climate variability could maintain the interaction between economic growth and urbanisation as a virtuous one. An empirical strategy combining a literature review, a descriptive analysis, and a PSTR model was designed to achieve the specified objectives. More specifically, the PSTR model was estimated using panel data from 32 Sub-Saharan African countries over the period 1990–2018 to obtain some interesting findings. The literature review pointed to several research avenues, among which: i) multivariate analyses of economic growth, urbanisation, and climate variability; (ii) measurement challenges with urbanisation and climate change; and (iii) modeling approaches. Quantitative results indicate that in Sub-Saharan Africa, urbanisation only has a positive effect on economic growth if the temperature variability is below the threshold of -0.4501, while the average temperature variability is around 0.5470.

Henderson *et al.* (2017) also documented a strong but differentiated link between climate and urbanisation in large panels of districts and cities in Sub-Saharan Africa, which has dried substantially in the past fifty years. The key dimension of heterogeneity was whether the cities were likely to have manufacturing for export outside their regions, as opposed to being exclusively market towns providing local services to agricultural hinterlands. Drier conditions increase urbanisation and total urban incomes in regions where cities are likely to be manufacturing centers (25% of sample). There, urban migration provides an "escape" from negative agricultural moisture shocks. However, in the remaining market towns (75% of sample), cities just service agriculture. Reduced farm incomes from negative shocks reduce demand for urban services and derived demand for urban labor. There, drying has little impact on urbanisation or total urban incomes. A lack of structural transformation in Africa inhibits a better response to climate change.

In summary, the literature review revealed conflicting results in the empirical analyses of the relationship between urbanisation and economic growth. These conflicting results can be justified by the lack of consensus on the indicators used to capture urbanisation and climate change, the sample size used, and the methods and techniques used in most of the studies.

According to Tahir, Haji, and Ali (2014), the results in the literature that happen to be mixed can be attributed to the issues of measurement of variables, endogeneity issues if dealing with panel data, sample selection, and quality of data. However, it is necessary to adapt more quality and efficient measures of variables in this study of urbanisation to determine the extent to which urbanisation affects growth.

However, given the discussion above, both directly and indirectly, climate change has a detrimental influence on the economies of the majority of tropical regions. This is crucial because the majority of the population in SSA relies heavily on rain-fed agriculture as their primary source of income. Therefore, a considerable impact on agricultural production, farm revenue, and food security, as well as a secondary impact on labor productivity, could result from a rising trend in temperature and an unpredictable precipitation future.

There are some limitations and criticisms associated with this body of research. Some common limitations and critiques are:

**Lack of Global Representation:** Many of the references may focus on specific regions, such as North America or Europe. This geographical bias can limit the generalizability of findings and overlook the unique challenges faced by cities in developing countries.

**Data Gaps:** Climate change and urbanisation research often rely on data that may be incomplete or outdated. This can result in inaccuracies in greenhouse gas emission inventories, land-use assessments, and vulnerability studies.

**Inconsistent Methodologies:** Different studies may use various methodologies and approaches to assess the impact of urbanisation on climate change. This variability can make it challenging to compare and synthesize findings effectively.

**Unclear Causality:** While urban areas contribute to climate change through their emissions, the references may not always provide a clear understanding of the causal links between urbanisation and climate impacts. This makes it difficult to quantify the precise contributions of cities to global climate change.

**Limited Socioeconomic Consideration:** Some references may focus primarily on environmental aspects of climate change and urbanisation, overlooking the social and economic dimensions. The unequal distribution of climate risks and benefits within cities may not be adequately addressed.

**Prescriptive vs. Descriptive:** Some literature may emphasize prescriptive solutions for mitigating climate change in cities but lack comprehensive descriptions of the current state of urban climate actions or the potential barriers to implementation.

**Interdisciplinary Gaps:** Climate change and urbanisation are inherently interdisciplinary subjects, but some research may not fully integrate knowledge from various fields, such as urban planning, environmental science, social sciences, and economics, which can limit the depth of analysis.

**Policy and Implementation Challenges:** The references may not delve deeply into the challenges of policy development, implementation, and enforcement in urban areas. Overcoming regulatory and political hurdles is crucial for effective climate action.

**Evolving Landscape:** The field of climate change and urbanisation is constantly evolving, and references may not reflect the most up-to-date research, policy developments, and technological advancements.

**Ethical and Equity Concerns:** Some critiques argue that urban climate policies may inadvertently exacerbate social inequalities if not carefully planned. The references may not comprehensively address these ethical concerns and trade-offs.

In conclusion, while the literature review provides a strong foundation for understanding the relationship between climate change and urbanisation, it's essential to acknowledge these limitations and critiques. Researchers in this field should be mindful of these challenges and strive for more comprehensive and inclusive analyses that consider both environmental and social aspects of urban climate change responses.

# CHAPTER THREE

# RESEARCH METHODS

## Introduction

This chapter presents the various procedures employed to achieve the study objectives. It begins with the research design and approach. The chapter also gives a detailed description of the theoretical and empirical model specifications; definition and measurement of variables in the model; estimation technique; sources of the data for the study; and the tools for data analysis.

## Research Design

Research design may reflect the totality of research process which involves conceptualizing a problem to the literature review, research questions, methodology of a study as well as conclusions (Harwell, 2011). Nonetheless, in another study (Harwell, 2011), research design refers only to the methodology of a study (for example, data collection and analysis). But this variation does not affect an examination of the role of research design in promoting rigorous study of promising ideas (Harwell, 2011).

The current study adopts the positivist philosophy and derives support from the neo-classical school of thought (Levin, 1988). Positivist philosophy allows the researcher to study social processes in an objective manner as well as explain relationships between variables. In addition, positivist philosophy is suitable for the development of mathematical models to investigate the relationship between quantitative measurements (Harwell, 2011).

The research design adopted in this study for data analysis follows the quantitative approach. The quantitative approach to research is founded on the assumptions and biases to guarantee objectivity in the conduct of the study and the inferences that are drawn (Harwell, 2011). Moreover, the quantitative approach is often described as deductive in nature, due to the fact that conclusions from tests of statistical hypotheses lead to general inferences about characteristics of a population. Quantitative methods are also frequently characterized as assuming that there is a single "truth" that exists, independent of human perception (Lincoln & Guba, 1985).

**Theorical model specification**

The study examines the significance of the effects of climate change and urbanisation on economic growth, along with various indicators. Determining the effects of climate change and urbanisation is a daunting exercise since there is no unified theoretical models to capture them in their entirety. However, following Lewis (1954), Todaro and Harris (1970), Cahuc and Célimène (1993), Lazafame (2014), Kuznets (1955), Henderson (2003),as well as Piguet

(2010), this study maintains the assumption that climate change and urbanisation adversely affect economic performance.

Aside from climate change and urbanisation, several indicators are also considered, including inflation as a measure of macroeconomic stability, labor force and trade openness, foreign direct investment, control for corruption, government effectiveness, political stability and gross fixed capital formation. These variables are selected based on data availability. The basic model therefore can be expressed as;

$$Y_{it} = \mu + X_{it}\beta + C_{it}\gamma_i + U_{it} \qquad (1)$$

Where $Y_{it}$ represents economic growth (or real GDP); $X_{it}$ is a vector of control variables that are perceived to be potential drivers of growth which consist of gross fixed capital formation (proxy for the investment rate), labour force, trade openness, foreign direct investment, inflation, exchange rate, political stability, control for corruption and Government effectiveness; $C_{it}$ is the vector of urbanisation and climatic variables consisting of temperature and precipitation and $U_{it}$ is the disturbance term.

**Empirical Model Specification**

From the existing empirical literature, the specification of our model follows Dell *et al*. (2009), Fay and Opal, (2000), Turok and McGranahan, (2013), Nassori, (2017), Amraoui, *et al.* (2011), Mayaki (2017), Lazafame (2014), Alagidede (2014), Dia (2021), Mendelsohn (2009), as well as Odusola and Abidoye (2012), the empirical model for the effects of climate change and urbanisation on economic growth can be specified. Thus, Equation (1) can be modified as

$$GRW_{it} = \beta_0 + \beta_1 URBANG_{it} + \beta_2 TEM_{it} + \beta_3 PREP_{it} + X_{it}\beta_4 + \eta_i + \mu_t + \varepsilon_{i,t} \quad (2)$$

Where GRW; represents Gross Domestic Product, which is a proxy for economic growth, TEM, represents temperature and PREP indicates precipitation. X is a vector of control variables. The control variables include; Trade openness, Inflation, Foreign Direct Investment, Labour force, Gross Fixed Capital Formation, Exchange rate, Political Stability, Government Effectiveness and Control for corruption. $\eta_i$ is country specific unobserved effect, $\mu_t$ represents time specific effect and $\varepsilon_{i,t}$ represents the idiosyncratic error term. The subscripts t and i denote country and time period respectively.

For purpose of estimation, equation (2) which gives the general specification is transformed into a behavioural equation for easy interpretation based of the research objectives.

To achieve objective one, the equation is first specified without the square of urbanisation.

$$GRW_{it} = \mu + \beta_1 URBANG_{it} + \beta_2 TRD_{it} + \beta_3 INF_{it} + \beta_4 FDI_{it} + \beta_5 LAB_{it} + \beta_6 GFC_{it} + \beta_7 EXCH_{it} + \beta_8 POST_{it} + \beta_9 Goveff_{it} + \beta_{10} CFCRP_{it} + U_{it} \quad (3)$$

To determine the non-linear relationship between urbanisation and growth, the urbanisation is then square. The urbanisation was squared to chapter the non-linear relationship between urbanisation and economic growth

$$GRW_{it} = \mu + \beta_0 URBANG_{it} + \beta_1 URBANG^2{}_{it} + \beta_2 TRD_{it} + \beta_3 INF_{it} + \beta_4 FDI_{it} + \beta_5 LAB_{it} + \beta_6 GFC_{it} + \beta_7 EXCH_{it} + \beta_8 POST_{it} + \beta_9 Goveff_{it} + \beta_{10} CFCRP_{it} + U_{it} \quad (4)$$

The second objective can be determined by interacting urbanisation with temperature

$$GRW_{it} = \mu + \beta_1 URBANGRP_{it} + \beta_2 URBANGRP * TEMP_{it} + \beta_3 TRD_{it} + \beta_4 INF_{it} + \beta_5 FDI_{it} + \beta_6 LAB_{it} + \beta_7 GFC_{it} + \beta_8 POST_{it} + \beta_9 Goveff_{it} + \beta_{10} CFCRP_{it} + U_{it} \quad (5)$$

The third objective can be determined by interacting urbanisation with precipitation.

$$GRW_{it} = \mu + \beta_1 URBANGRP_{it} + \beta_2 URBANGRP * PREP_{it} + \beta_3 TRD_{it} + \beta_4 INF_{it} + \beta_5 FDI_{it} + \beta_6 LAB_{it} + \beta_7 GFC_{it} + \beta_8 POST_{it} + \beta_9 Goveff_{it} + \beta_{10} CFCRP_{it} + U_{it} \quad (6)$$

Finally, the fourth objective can be determined by squaring the climate change variables (temperature and precipitation). The temperature precipitation was squared to chapter the non-linear relationship between temperature, precipitation and economic growth as specified in equations 8 and 9

$$GRW_{it} = \mu + \beta_1 TEM_{it} + \beta_2 TRD_{it} + \beta_3 INF_{it} + \beta_4 FDI_{it} + \beta_5 LAB_{it} + \beta_6 GFC_{it} + \beta_7 EXCH_{it} + \beta_8 POST_{it} + \beta_9 Goveff_{it} + \beta_{10} CFCRP_{it} + U_{it} \quad (7)$$

$$GRW_{it} = \mu + \beta_1 TEM_{it} + \beta_2 TEM_{it}{}^2 \beta_3 TRD_{it} + \beta_4 INF_{it} + \beta_5 FDI_{it} + \beta_6 LAB_{it} + \beta_7 GFC_{it} + \beta_8 POST_{it} + \beta_9 Goveff_{it} + \beta_{10} + U_{it} \quad (8)$$

$$GRW_{it} = \mu + \beta_1 PREP_{it} + \beta_2 TRD_{it} + \beta_3 INF_{it} + \beta_4 FID_{it} + \beta_5 LAB_{it} + \beta_6 GCF_{it} + \beta_7 EXCH_{it} + \beta_8 POST_{it} + \beta_9 Goveff_{it} + \beta_{10} CFCRP_{it} + U_{it} \quad (9)$$

$$GRW_{it} = \mu + \beta_1 PREP_{it} + \beta_2 PREP_{it}{}^2 + \beta_3 TRD_{it} + \beta_4 INF_{it} + \beta_5 FDI_{it} + \beta_6 LAB_{it} + \beta_7 GFC_{it} + \beta_8 POST_{it} + \beta_9 Goveff_{it} + \beta_{10} + U_{it} \quad (10)$$

Where URBANG represents urbanisation (urban growth), TEM represents temperature, PREP represents precipitation, INF represents inflation rate, TRD represents international trade, FDI represents foreign direct investment, LAB represents labour force, EXCH represents real exchange rate, POST represents Political Stability, GOVEEF represents Government Effectiveness and CFCRP represents Control for Corruption. $\mu$, is a constant term, $\beta_1$, $\beta_2$, $\beta_3$, $\beta_4$, $\beta_5$, $\beta_6$ , $\beta_7$ , $\beta_8$, $\beta_9$, $\beta_{10}$ are the coefficient of urbanisation, trade openness, inflation, foreign direct investment, labour force, gross fixed capital formation, Political Stability, Government Effectiveness and Control for Corruption. $U_{it}$ is the error term, which is assumed to be uncorrelated with the explanatory variables from equation 3.

**Description of Variables and Justification**

This section provides a vivid understanding of the variables used for the study and justification for their choices. For the purpose of this study, the following measurement and operational definitions were used for the variables being examined: The variables included in the study are real GDP (economic growth), climate change, urbanisation, trade openness, FDI, real effective exchange rate, inflation, gross fixed capital formation (capital), political stability, government effectiveness, control for corruption, and population.

The choice of the variables was based on extant literature, economic theory, available data and their significance to the study. The basis for the signs of the respective coefficients of the variables is explained in the description of the variables below.

**Economic growth**

Economic growth is defined as the sustained increase in a country's real output or real gross domestic product overtime (Demetriades & Hussein, 1996).

In this study, real GDP is be used as a proxy for economic growth instead of GDP growth rate or GDP per capita since it is the most popular measure of economic growth in the literature and is mostly used by the Breton Wood Institutions. Besides, this measure is preferred to other measures because it nets out the effect of inflation on the price of the goods and services produced by adjusting inflation terms.

Economic growth is used as the dependent variable in the model. Thus, real GDP is used as a proxy for economic growth. Ayadi and Ayadi (2008) employed real gross domestic product as a proxy of economic growth in examining the impact of external debt and trade openness on economic growth for Nigeria and South Africa.

**Urbanisation**

Urbanisation, which is seen as a critical component in a country's growth, has a variety of definitions. Bairoch (1988) and Nassori (2017) conceptualised as a multifaceted dynamism that might come from a shift over time, such as a migration of rural populations to urban regions, or from an increase in the urban population that is quicker than the rural population increase (Nassori, 2017).

Urbanisation is captured by the rate of growth in urban population. Unlike the expression as a percentage of total population (Nguyen and Nguyen, 2018), the growth rate conveys a better understanding of the level of variation experienced by urbanisation in Sub-Saharan Africa from one period to the next. Urbanisation has a mixed effect on economic growth in the area of agricultural productivity, industrialization and low cost of labour, Urbanisation is expected to improve economic growth through cheaper labour. restructuring and industrialization as well as investments and education opportunities. Also, urban growth generates revenues that fund infrastructures projects reducing congestion and improving public health and all these enhance growth. Contrary, urbanisation also has some negative effects, such as traffic, violence, increased pollution, communicable diseases, unemployment, water scarcity, overcrowding, sanitation problems and physical inactivity that affect labour productivity and thus, hinders economic growth. The literature generally uses the urban predominance indicator and the urban population ratio as a measure of urban growth.

Therefore, this study deviates from these traditional measures and adopt a new measure of urbanisation proposed by James G. and Yu O. (2021). The authors distinguished between residual urbanisation and Natural urbanisation as follows : Urban Natural Increase = Total Urban Increase$-\left(\frac{Urban\,birth - Urban\,death}{Total\,population} * 100\right)$

James G. and Yu O. (2021) calculated urban residual increases in urbanisation as the difference between total urban increase and urban natural increase : Urban Residual Increase = Total Urban Increase − Urban Natural Increase. In this formulation, urban residual increase captures both internal migrations, i.e., the movement of a country's population from rural to urban, and reclassification, which is the process by which a municipal area is reclassified from rural to urban. It is expected that the coefficient of urbanisation will be either less than or greater than zero ( $\beta_1 < 0\ or\ \beta_1 > 0\ \ for\ urbanization\ \ variable\ in\ equation\ 3$ )

**Climate Change**

The Intergovernmental Panel Climate change (IPCC) defines climate change broadly as "any change in climate over time whether due to natural variability or as a result of human activity**."** Whiles the Framework Convention on Climate Change (FCCC) defines climate change as "a change of climate that is attributed directly or indirectly to human activity, that alters the composition of the global atmosphere, and that is in addition to natural climate variability over comparable time periods."

Thus, we can say that Climate change commonly refers to significant changes in global temperature, precipitation, wind patterns and other measures of climate that occur over several decades or longer. The volume of precipitation and temperature are commonly used as indicators of climate change in most studies (Harari & Ferrara, 2012). The studies deployed precipitation and temperature as the proxy for climate change in this study. Economic impact of climate change includes.

I. Economic damages to residential and commercial properties as a result of sea level rise, and the ripple effects of these damages on local and regional economic performance

II. Costs of illness associated with extreme heat events and urban heat island effects

III. Changes in forest sector, crop and livestock yields, and harvest values due to long term changes in temperature and precipitation patterns

IV. Decreased economic returns from irrigation investments due to changes in future water supply conditions

V. Increased forest management costs due to increased drought and temperature-related wildfire risks

VI. Changes in hydropower generation and revenues associated with increased rainfall variability

VII. Optimal power generation technologies and electric grid integration feasibility to align with Paris Agreement commitments and de-carbonization targets

VIII. Altered migration patterns within the SSA due to shifting temperature and precipitation patterns

IX. Changes in residential amenity values associated with alterations in climatic conditions.

Based on the above explanations, we expect climate change to have a negative relationship with economic growth. That is the coefficient of the climate change variables to be less than zero ( $\beta_1 < 0$ for temperature in equation 7 and $\beta_1 > 0$ for precipitation in equation (9).

**Trade openness (OPEN)**

Trade openness refers to the degree to which nationals and foreigners can transact trade without artificial (that is, governmentally imposed) costs, including delays and uncertainty. Trade openness is often hypothesized to raise growth through several channels from the literature such as, greater access to a variety of inputs for production, access to advanced technology from abroad, possibilities of catch-up, and access to broader markets that raise the efficiency of domestic production through increased specialisation. Various measures of openness have been proposed and tested, with no single 'best' measure emerging.

Asiedu (2013) in examining Trade Liberalisation and Growth in SSA used the sum of exports and imports of goods and services measured as ratio to GDP as a measure of openness. Frequently used measures include the ratio of total trade to GDP and changes in terms of trade. Trade openness enhances competition, promotes large markets, enhances technology transfer and hence efficiency in production. It is thus expected that trade openness will have a positive relationship with economic growth. Therefore, its coefficient $\beta_2$ is expected to be positive. Thus, $\beta_2 > 0$

**Inflation (INF)**

Inflation is defined as a sustained increase in the general prices of goods and services over a period of time. A host country's economic instability can be a major deterrent to economic growth. Price stability is an indicator of a stable macroeconomic environment of a country. Usually, high rate of inflation in a country can reduce the return on investment and an indicator of macroeconomic instability and considered a sign of internal economic tension and unwillingness of the government to balance its budget and failure of the central bank to conduct appropriate monetary policy (Schneider & Frey, 1985).

Inflation (INF) as measured by the consumer price index reflects the annual percentage change in the cost to the average consumer of acquiring a fixed basket of goods and services that may be fixed or changed at specified intervals, such as yearly. Inflation rate is a reflection of macroeconomic instability. A high rate of inflation is generally harmful to growth because it raises the cost of borrowing and thus lowers the rate of capital investment. However, at low levels of inflation, the likelihood of such a trade-off between inflation and growth is minimal. Inflation is therefore used as an indicator to capture macroeconomic instability (Asiedu & Lien, 2004; Asiedu, 2013; & Ayibor, 2012). It is expected that $\beta_3 < 0$.

**Foreign Direct Investment (FDI)**

Foreign direct investment (FDI) is defined as investment made to acquire a lasting management interest possibly 10 percent or more of voting stock in enterprises operating outside of the economy of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown on the balance of payments. It is expressed as a ratio to GDP. Foreign Direct Investment is considered as an inflow of foreign capital to complement domestic investment and production and hence improving economic performance. Following the works of Lipsey (2001), Frimpong and Oteng-Abayie (2006); Asiedu (2013), and Esso (2010), this study uses FDI as a share of GDP to measure foreign direct investment.

The role of foreign direct investment (FDI) has been widely recognized as a growth-enhancing factor in developing countries. It is therefore expected that an increase in foreign direct investment leads to an increase in total investment and hence increase in total output and its rate of growth. Thus, its coefficient $\beta_4$ is expected to be positive. Thus $\beta_4 > 0$.

**Labour Force (LAB)**

Labour force (labour participation rate) is chosen instead of population growth because it denotes a proportion of the total population aged between fifteen (15) and sixty-four (64) years and is the active and productive population in the country. Solow (1956) and Swan (1956) advised that labour force should be included in the growth model because of its effect on the work force and this has been proven empirically in many researches that included labour force to be a good measure of economic growth. Labour force as a proxy for labour participation rate has been used in several other studies such as Frimpong and Oteng-Abayie (2006), Sakyi (2011) and Ayibor (2012). It is expected that $\beta_5 > 0$.

**Gross Fixed Capital Formation (K)**

Gross fixed capital formation (K) formerly gross domestic fixed investment includes plants, machinery and equipment. It also includes the construction of roads, railways, and others such as schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings and all these are necessary for economic growth. The variable is used as a proxy for capital stock. Gross fixed capital formation as a proxy for capital has been used in several other studies such as Balasubramanyam, Salisu, and Sapsford (1996), Kohpaiboon (2006), Mansouri (2005), as well as Njindan Iyke and Takumah, (2015). Gross fixed capital formation as a percentage of GDP (a proxy for capital stock) is expected to positively affect real GDP growth. The higher the rate of investment the higher the growth rate of the economy, ceteris paribus, therefore $\beta_6 > 0$.

**Real Effective Exchange Rate (REER)**

Real Effective Exchange Rate is the weighted average of a country's currency relative to an index or basket of other major currencies adjusted for the effects of inflation. When real effective exchange rate increases, it is an indication of real depreciation of local currency relative to other foreign currencies. Depreciation of the local currency stimulates exports and hence growth rate is also influenced positively. Even though import volume decreases, the value of imports increases in domestic currency terms because the currency has depreciated.

An appreciation of the domestic currency makes exports from the home country more expensive and so decreases demand for home country's exports and foreign exchange earnings and hence hampering economic growth. Thus, the study anticipates a positive relationship between real effective exchange rate and economic growth. Thus $\beta_7 > 0$.

**Political Stability (POST)**

Political Stability and Absence of Violence/ Terrorism measures perceptions of the likelihood of political instability and/or politically-motivated violence, including terrorism. Ranges from –2.5 (least stable) to +2.5 (most stable) and it is expected to be positive. Thus, $\beta_8 > 0$

**Government Effectiveness (GOVEFF)**

Government Effectiveness reflects perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies. Ranges from –2.5 (least effective) to +2.5 (most effective). However, government effectiveness is expected to be positive. Thus, $\beta_9 > 0$

**Control for Corruption (CFCRP)**

Control of Corruption reflects perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture "of the state by elites and private interests. Ranges from –2.5 (very corrupt) to +2.5 (least corrupt) control for corruption is expected to be positive. Thus, $\beta_{10} > 0$.

**Table 1: Summary of Variables and Anticipated Effects**

| Independent Variables | Notation | Expectations |
|---|---|---|
| URBANG | Urban Growth Rate | Positive |
| TEMP | Average Temperature | Negative |
| PREP | Precipitation (Mm) | Positive |
| TRD | Trade Openness | Positive |
| FDI | Foreign Direct Investment | Positive |
| INF | Inflation | Negative |
| LAB | Labour Force | Positive |
| GFCF | Gross Fixed Capital Formation | Positive |
| RECHG | Real Exchange Rate | Positive |
| POST | Political Stability | Positive |
| CFCRP | Control for Corruption | Positive |
| GOVEFF | Government Effectiveness | Positive |

Source: Mba (2022)

## Data Source and Estimation Technique

### Data Source

The study uses secondary data from world development indicators (WDI) and NASA Power database collaborated by NASA climate change data as well as data from UNdata base (2019) from 2000 to 2020 for a balanced panel of 32 sub-Saharan African countries. The source of data for the study is summarized below.

**Table 2: Source of data**

| Variables | Variable Description | Sources |
|---|---|---|
| Urbanisation | Growth Rate of Urban Population (%) | WDI and UNdata |
| Temperature | Average Temperature (°C) | NASA Climate Data Base |
| Precipitation | Average Rainfall (Mm) | NASA Climate Data Base |
| Inflation | Consumer Price Index | WDI |
| Foreign Direct Investment | Foreign Capital Inflows as % of GDP | WDI |
| Labour Force | Labour Participation Rate (15 To 64 Years) | WDI |
| Exchange Rate | Weighted Average of a Country's Currency | WDI |
| Gross Fixed Capital Formation | A Proxy for Capital Stock | WDI |
| Climate index | Using the first principal component | Computed using PCA |
| Political Stability | Ranges from –2.5 (least stable) to +2.5 (most stable) | WDI |
| Control for Corruption | Ranges from –2.5 (very corrupt) to +2.5 (least corrupt) | WDI |

| | | |
|---|---|---|
| Government Effectiveness | Ranges from –2.5 (least effective) to +2.5 (most effective) | WDI |

Source: Mba (2022).

**Estimation Technique**

The study employed the dynamic panel-data GMM estimator proposed by Arellano and bond (1991) and developed by (Blundell & Bond, 1998).

A panel model contains two subscript (i and t) which differentiate it from either cross-sectional (i) or time series (t). Thus, a panel data can be seen as a time series of individual cross-sections and hence has the attributes of both time series and cross- sectional data. Panel data therefore has some superiority over pure cross sectional or time series data especially its ability to handle individual heterogeneity (Greene, 2003). The estimation technique employed must therefore be able to handle both attributes to ensure efficient and consistent estimates.

There are several specifications of a panel model but the type specified in this study assume an individual varying effect which is constant over time ($\alpha_i$). This specification allows the variations in the dependent variable to be attributed to the explanatory variables after controlling for individual effects (Greene, 2003). The estimation of the dynamic model cannot be done the usual way of estimating static panel models because of the inclusion of the lag dependent variable as an explanatory variable. That is, the introduction of the lag-dependent variable as an explanatory variable has the tendency of creating endogeneity in the model.

To avoid the tendency of biasedness due to the problem of endogeneity an alternative estimator may be necessary to estimating the model. The available options are the GMM instrumental variable (IV) estimator and direct bias corrected estimators (Behr, 2003). In the case of endogenous predetermined regressors, the system estimator proposed by Blundell and Bond (1998) is unbiased and most efficient, while the direct biased corrected estimators perform similar to the GMM-estimator proposed by Arellano and Bond in 1991 (Behr, 2003). The concept of instrumental variable estimations requires identifying an instrument that will be able to mitigate the problem of endogeneity in the model. However, a major drawback in the basic instrumental variable model (IV) has to do with the ease with which a valid and relevant instrument can be located and used (Wooldridge, 2002).

To minimize the task of searching for an appropriate instrument; several authors have developed a variant of the IV estimator that uses the lags of the variables in the models (Anderson & Hsio, 1982; Arrelano & Bond, 1991; Arellano & Bover, 1995; Blundell & Bond, 1998). According to Arellano-Bond (1991) as many as $\frac{1}{2}(T(T-1))$instrument can be generated from N*T panel data, where N is the number of individual observation and T is the maximum time period. The data for this study includes 21 time periods (T=21).

The behaviour of the economic variables is intrinsically dynamic and this can account for using panel data models as opposed to the use of cross-sectional models which can only ascertain the behavioral pattern at a particular point and therefore cannot be used to capture substantial behaviour dynamics over a period of time only limited itself to one unit and, therefore, are unable to compare changes in the behavior of different economic agents. These dynamics can neither be captured by cross-sectional framework nor time series models.

However, since panel data sets provide time series on each cross-sectional unit in a group, it becomes relatively easy to evaluate the changes in the behavior pattern using the data. More, notably, if the micro units are heterogeneous, policy prescriptions drawn from time series aggregate data may be invalid. Panel data containing time series observations for a number of individuals is deal for investigating "homogeneity" versus "heterogeneity" issue (Hsiao, 2006).

**Differences Generalized Method of Moment (GMM)**

The Difference GMM correct for endogeneity problems by transforming all regressors through differencing hence removing fixed effect. However, Difference GMM is particularly vulnerable to weak instruments, which can lead to imprecise or inconsistent parameter estimates. Weak instruments occur when the instruments used in the estimation are not highly correlated with the endogenous variables, making it difficult to identify the true relationships in the model. In such cases, the GMM estimators can produce unreliable results, including standard errors that are biased downwards (Arelleno and Bond, 1991). The difference GMM is specify as follows:

$Y_{it} = \mu + \emptyset Y_{it-1} + X_{it}\beta + U_{it}$ Were

$U_{it} = \eta_t + \varepsilon_{it}$(8)

Transformed model

$$\Delta Y_{it} = \emptyset \Delta Y_{it-1} + \Delta X_{it}\beta + \Delta \varepsilon_{it} \quad (9)$$

By transforming the regressors through the first differencing the fixed effect is removed as it does not vary with time but the problem of endogeneity remains since the lag of dependent variable still correlate with the error term. That is

$$\Delta\mu_{it} = \Delta\eta_t + \Delta\varepsilon_{it} \qquad (10)$$

$$U_{it} - U_{it-1} = (\eta_i - \eta_i) + (\varepsilon_{it} - \varepsilon_{it-1}) = \varepsilon_{it} - \varepsilon_{it-1} \qquad (11)$$

The unobserved fixed effect no longer enters the equation as they are by assumption constant between periods and also the first differenced lagged dependent variable is instrumented with its past levels and now changes in the dependent variable are assumed to be present in equation (11).

**System GMM**

Using equation (9) and assuming that it's a random walk model and Y is persistent, that is, the dependent variable is persistent. If that is the case, applying the difference GMM will yield both biased and inefficient estimates of in a finite sample, and this is particularly acute when T is short.

The poor performance of the difference GMM estimator is attributed to the use of poor instruments (Blundell & Bond, 1998). Thus, in this case, the system GMM is applicable because of the following reasons: it will express the one equation in level form with the first difference as instruments. Also, it expressed the second equation as the first difference form with levels as instruments. The approach involves the use of a greater number of moment conditions, but Monte Carlo evidence suggests that when T is short and the dependent variable is persistent, then there are gains in precision and the small sample bias is reduced. Base on the theoretical and empirical model specification, the system GMM is empirically specified as follows, based on the objective of this study and following Blundell and Bond (1998), Arelleno and Bond (1991) and Arellano and Bover (1995). System GMM can help address endogeneity problem as follows:

Instrumental Variables (IV) Approach: System GMM extends the traditional GMM framework by using additional moment conditions derived from instruments to instrument endogenous variables. It employs a system of equations, including the first-differenced equation and the level equation, to estimate the parameters. These instruments are typically lagged levels and first-differences of the variables in the model.

Orthogonal Instruments: System GMM relies on instruments that are orthogonal (uncorrelated) to the error term. This orthogonality condition ensures that the instruments are exogenous, meaning they are not influenced by the unobserved factors affecting the endogenous variables. The use of lagged variables as instruments is often based on the assumption that past values of variables are exogenous to current values.

Addressing Simultaneity and Dynamics: System GMM explicitly accounts for both the dynamic nature of the data and the possibility of simultaneous relationships between variables. This is especially important in panel data models where lagged dependent variables are used as explanatory variables, as this can introduce endogeneity due to feedback effects.

Efficient Estimation: System GMM is known for providing more efficient and consistent estimates in dynamic panel data models compared to other estimation methods. It helps alleviate the "Nickell bias" that is often associated with traditional fixed effects or first-differenced estimators.

Consistency and Asymptotic Normality: When used correctly, System GMM provides consistent and asymptotically normally distributed parameter estimates. This means that as the sample size increases, the estimated parameters will converge to the true values and follow a normal distribution, making statistical inference more reliable.

Control for Unobserved Heterogeneity: System GMM effectively controls for unobserved individual or time-specific effects, making it suitable for panel data where such effects are common.

The System GMM model specification is as follows;

$$Y_{it} = \mu + \delta Y_{i,t-1} + X_{it}\beta + C_{it}\gamma_i + U_{it} \quad (11)$$

Where i=1, 2……N; t=1…. 2, T , $U_{it} = \mu_i + \varepsilon_{it}$

Where $\beta_1$, $\beta_2$…….$\beta_{10}$ are the parameters to be estimated, µ is a constant parameter and $U_{it}$ is the error term $\delta$ is the coefficient of the lag of GDP.

The lagged dependent variable was included in the model because of the following reasons;

**Endogeneity and Autoregression**: Including the lagged dependent variable help address potential endogeneity issues. Endogeneity occurs when a variable is correlated with the error term in a regression model. By including the lagged dependent variable on the right-hand side, you are capturing the past values of the dependent variable, which might help control for unobserved factors that affect the current value of the dependent variable.

**Dynamic Effects**: In many economic processes, the current value of a variable is influenced by its past values. Including lagged values allows the model to capture the dynamic nature of economic relationships and how past values affect the present.

**Persistence and Memory**: Economic variables often exhibit persistence or memory, meaning that their past values have a lasting impact on their current values. Including lagged values acknowledges this persistence and helps model the inherent inertia in economic processes.

**Time-Series Data**: In time-series data, where observations are taken at different points in time, lagged values are essential for capturing patterns and trends. Including lags allows the model to account for temporal dependencies.

**Statistical Considerations**: Including lagged dependent variables can also improve the statistical properties of the estimation, especially if there is serial correlation in the error terms. It can help correct for issues related to autocorrelation

To achieve the first objective, which estimate the intensity of urbanisation on growth in the sub-Sahara region, the study first specified a model without accounting for non-linearity and it is specify as follows;

$$GRW_{it} = \mu + \delta GRW_{it-1} + \beta_1 URBANG_{it} + \beta_2 TRD_{it} + \beta_3 INF_{it} + \beta_4 FDI_{it} + \beta_5 LAB_{it} + \beta_6 GFC_{it} + \beta_7 EXCH_{it} + \beta_8 POST_{it} + \beta_9 Goveff_{it} + \beta_{10} CFCRP_{it} + U_{it} \quad (12)$$

However, accounting for the possibility of non-linear relationship between urbanisation and growth, the model is defined as;

$$GRW_{it} = \mu + \delta GRW_{it-1} + \beta_0 URBANG_{it} + \beta_1 URBANG^2{}_{it} + \beta_2 TRD_{it} + \beta_3 INF_{it} + \beta_4 FDI_{it} + \beta_5 LAB_{it} + \beta_6 GFC_{it} + \beta_7 EXCH_{it} + \beta_8 POST_{it} + \beta_9 Goveff_{it} + \beta_{10} CFCRP_{it} + U_{it} \quad (13)$$

To achieve the second objectives that determine the moderating role of temperature in the urbanisation -economic growth relationships, we specify the interaction equation as follows;

$$GRW_{it} = \mu + \delta GRW_{it-1} + \beta_1 URBANGRP_{it} + \beta_2 URBANGRP * TEMP_{it} + \beta_3 TRD_{it} + \beta_4 INF_{it} + \beta_5 FDI_{it} + \beta_6 LAB_{it} + \beta_7 GFC_{it} + \beta_8 POST_{it} + \beta_9 Goveff_{it} + \beta_{10} CFCRP_{it} + U_{it} \quad (14)$$

The third objective of the study that determines the moderating role of precipitation in the urbanisation -economic growth relationship was specified in the interaction equation below.

$$GRW_{it} = \mu + \delta GRW_{it-1} + \beta_1 URBANGRP_{it} + \beta_2 URBANGRP * PREP_{it} + \beta_3 TRD_{it} + \beta_4 INF_{it} + \beta_5 FDI_{it} + \beta_6 LAB_{it} + \beta_7 GFC_{it} + \beta_8 POST_{it} + \beta_9 Goveff_{it} + \beta_{10} CFCRP_{it} + U_{it} \quad (15)$$

$$GRW_{it} = \mu + \delta GRW_{it-1} + \beta_1 TEM_{it} + \beta_2 TRD_{it} + \beta_3 INF_{it} + \beta_4 FDI_{it} + \beta_5 LAB_{it} + \beta_6 GFC_{it} + \beta_7 EXCH_{it} + \beta_8 POST_{it} + \beta_9 Goveff_{it} + \beta_{10} CFCRP_{it} + U_{it} \quad (16)$$

Finally, the fourth objectives which examine the non-linear relationship between economic growth and the climate change variables was also achieved with the following equations.

$$GRW_{it} = \mu + \delta GRW_{it-1} + \beta_1 TEM_{it} + \beta_2 TEM_{it}{}^2 \beta_3 TRD_{it} + \beta_4 INF_{it} + \beta_5 FDI_{it} + \beta_6 LAB_{it} + \beta_7 GFC_{it} + \beta_8 POST_{it} + \beta_9 Goveff_{it} + \beta_{10} CFCRP_{it} + U_{it} \quad (17)$$

$$GRW_{it} = \mu + \delta GRW_{it-1} + \beta_1 PREP_{it} + \beta_2 TRD_{it} + \beta_3 INF_{it} + \beta_4 FID_{it} + \beta_5 LAB_{it} + \beta_6 GCF_{it} + \beta_7 EXCH_{it} + \beta_8 POST_{it} + \beta_9 Goveff_{it} + \beta_{10} CFCRP_{it} + U_{it} \quad (18)$$

$$GRW_{it} = \mu + \delta GRW_{it-1} + \beta_1 PREP_{it} + \beta_2 PREP_{it}^{\ 2} + \beta_3 TRD_{it} + \beta_4 INF_{it} + \beta_5 FDI_{it} + \beta_6 LAB_{it} + \beta_7 GFC_{it} + \beta_8 POST_{it} + \beta_9 Goveff_{it} + \beta_{10} CFCRP_{it} + U_{it} \quad (19)$$

i=1, 2, …., N  t=1,2, …, T, $\alpha_i$= fixed effect

Since a static model will not capture the short and long-run impacts of the regressors on the dependent variable coupled with the problems of the difference GMM, the system GMM estimator was employed to capture the persistent nature of economic growth and address the problems of omitted variables, measurement error, endogeneity, and country-specific heterogeneity. The study therefore settled on the Blundell and Bond (1998) system GMM approach to estimate the dynamic mode.

Machine learning models can be used as an alternative technique in this study because Machine learning models can capture non-linear relationships and complex interactions among variables. In the context of urbanization, climate change, and economic growth, these relationships are likely to be intricate and may not be fully captured by traditional linear models

**Post Estimation Diagnostics**

The GMM Model estimators have not imposed a lot of assumptions on the error term. Because there are fewer assumptions on the error term, there are very few post-estimation tests required after a GMM model estimation (Wooldridge, 2002).

Two well-known tests are needed after the Arrelano and Blundell estimations (Blundell & Bond, 2000). The first is the Arrelano and Bond test of autocorrelation (AR-TEST), The AR-TEST reports the test statistics for the first and second difference autocorrelation in default mode, but the lag levels can be adjusted. It has a null hypothesis of no autocorrelation in the first difference error. Thus, it is required that the null hypothesis be rejected. That is, the bigger the probability value of the AR-TEST, the less the problem of autocorrelation in the model.

A solution to the autocorrelation problem is to estimate the two-step equation. In two-step estimation, the standard covariance matrix is robust to panel-specific autocorrelation and heteroskedasticity, but the standard errors are downward biased (Mileva, 2007). The second test is the Sargan test of valid over-identifying restrictions. It has a null hypothesis of correct over-identifying restrictions, which requires that we must fail to reject the null. Just as in the case of the AR-TEST.

The diagnosis test is conducted to ensure that the model and technique for estimation are robust, unbiased efficient and has consistent estimates to obtained reliable and valid results.

It's crucial to address endogeneity issues, particularly in the context of climate-related variables like temperature and precipitation. One common instrument used in studies is the instruments related to geographic or climatic factors. These instruments can help address endogeneity and improve the validity of your results.

**Geographic or Climatic Instruments:**

Distance to Coastline: The distance to the coastline can be used as an instrument for temperature and precipitation variables. Coastal areas generally have milder temperatures and receive different patterns of precipitation compared to inland areas. By using the distance to the coastline as an instrument, you can capture the exogenous variation in climate variables that may affect economic growth independently of the growth process itself (Levi et al.,2002).

Elevation: Elevation can be another useful instrument, as it affects temperature and precipitation patterns. Higher elevations are often cooler, while lower elevations may experience different levels of precipitation. Using elevation as an instrument can help address endogeneity in your climate variables.

Geographic and climatic factors like distance to the coastline and elevation are often considered exogenous to economic growth. They are determined by natural processes and geographical features rather than being influenced by economic activity.

These instruments provide plausible sources of exogenous variation in temperature and precipitation. In other words, changes in distance to the coastline or elevation are not driven by changes in economic growth.

By using these instruments, you can better isolate the causal effect of climate variables on economic growth, minimizing the risk of reverse causality, where economic conditions may also influence climate patterns.

Geographic or climatic instruments have been commonly used in environmental and climate-economic studies to address endogeneity concerns. They are well-established and widely accepted in the literature (Mileva, 2007).

**Panel Unit Root Test**

Another important aspect of the GMM diagnostic test is the panel unit root test. Most macroeconomic variables, such as inflation, the exchange rate, and real gross domestic product (GDP), exhibit trending behavior. The trend behavior can be due to a stochastic process or a deterministic trend, which can lead to incorrect conclusions when used in any analysis.

An important econometric task is determining the most appropriate form of trend in the data. The Panel unit root test is an update or extension of the simple time series scenario by making use of the cross-sectional dimension.

The main objective of the panel unit root tests is the desire to increase the power of the unit root tests by increasing the sample size. The panel unit root test is divided roughly into two categories: the so-called first-generation panel unit root test, which assumes that the cross-sectional units are independent; the two panel unit tests belonging to this category are the tests proposed by Levi et al. (2002) and Im et al. (2003), usually represented by the LLC test and the IPS test, respectively. However, both methods assume cross-sectional dependence but allow for heterogeneous individual deterministic terms and heterogeneous serial correlation of the residuals. Both tests test the same hull hypothesis and alternative hypothesis.

$H_O$ : Panels contain unit roots

$H_O$: Panels are stationary

The decision rule is that if the p value is less than the 5% significant level then the null hypothesis would be rejected and conclude that the panel data is stationary otherwise, we would fail to reject the null hypothesis if the p value is greater than the 5% level of significance and say that the panel data contains unit root. Other test for Stationarity in panel includes Breitangis test (2000), and Levin and Lin test (1992).

However, the study adopted the LLC and Im IPS test due to the reasons as cited by Maddala and Wu (2001), Choi (2001), Hlouskora and Wagner (2006). Unit root test is conducted to ensure that variables are stationary and to prevent the occurrences of spurious regression

**Granger Causality Tests**

To achieve the final objective of the study, which is to determine the direction of causality between temperature, precipitation and urbanisation in sub-Saharan Africa, the study adopts the Grange causality test proposed by Engel and Granger (1987).

The study of causal relationships among economic variables has been one of the main objectives of empirical econometrics. According to Engle and Granger (1987), cointegrated variables must have an error correction representation. "Granger causality" is a term for a specific notion of causality in any analysis. If Y can be explained or predicted using the histories of both X and Y, it can be explained or predicted using the history of Y alone. Grange-causality is, thus, a powerful tool, in that it allows one to test for things that one might otherwise assume or otherwise take for granted.

One of the implications of the Granger representation theorem is that if non-stationary series are cointegrated, then one of the series must granger cause the other (Gujarati, 2009). To examine the direction of causality in the presence of cointegrating vectors, Granger causality is conducted based on the following:

$$\Delta Y_{it} = \delta_0 + \int_{i=1}^{p} \beta_{1i}\, \Delta Y_{t-i} + \int_{i=0}^{p} \emptyset_{1i}\, \Delta X_{it-i} + \omega_{1i} ECT_{t-1} + \mu_t \ldots\ldots\ldots\ldots\ldots (16)$$

$$\Delta X_{it} = \delta_0 + \int_{i=1}^{p} \beta_{2i}\, \Delta X_{t-i} + \int_{i=0}^{p} \emptyset_{1i}\, \Delta Y_{it-i} + \omega_{2i} ECT_{t-1} + \varepsilon_t \ldots\ldots\ldots\ldots (17)$$

Where ΔY and ΔX are the non-stationary dependent and independent variables, ECT is the error correction term, $\omega_{1i}$and $\omega_{2i}$ are the speed of adjustments, p is the optimal lag order while the subscripts t and t-i denote the current and lagged values. To find out whether the independent variable (X) granger-causes the dependent variable (Y) in equation (16), we examine the joint significance of the lagged dynamic term by testing the null hypothesis:

$H_0 : \emptyset_{1i} = 0$

Implying that the explanatory variable (X) does not granger cause the dependent variable (Y), against the alternative hypothesis that

$H_1 : \emptyset_{1i} \neq 0$

Implying that the explanatory variable (X) granger causes the dependent variable (Y)

Similarly, to find out whether the independent variable (Y) granger cause the dependent variable (X) in equation (17), we examine the significance of the lagged dynamic term by testing the null hypothesis:

$H_0 : \emptyset_{2i} = 0$

Implying that the independent variable (Y) does not granger cause the dependent variable (X), against the alternative hypothesis that

$H_1 : \emptyset_{2i} \neq 0$

Implying that the explanatory variable (Y) granger causes the dependent variable (X) Using the standard F-test or Wald statistic, four possibilities exist:

First, rejection of the null hypothesis in equation (16) but failing to reject the null in equation (17) at the same time implies unidirectional causality running from X to Y. Second, a rejection of the null hypothesis in equation (17) but at the same time failing to reject the null in equation (16) implies unidirectional causality running from Y to X. Third, simultaneous rejection of the two null hypotheses indicates bi-directional causality. Fourth, simultaneous failure to reject the two null hypotheses indicates independence or no causality between the variables of interest.

**Data Analysis**

The study employs both descriptive and quantitative analysis. Charts such as graphs and tables are employed to aid in the descriptive analysis. The system GMM estimator is employed to capture the persistent nature of economic growth. The choice of this model is due to the fact that it addresses the problems of omitted variables, measurement error, endogeneity, and country-specific heterogeneity.

The consistency of the system-GMM estimator is assessed by some diagnostics tests such as the Hansen test of over-identifying restrictions tests for the overall validity of the instruments; an autocorrelation or serial correlation test to examine the null hypothesis that the error term is not serially correlated; a stationarity test and multicollinearity test are also carried out. To obtain the estimates of the variables involved, all estimations are carried out using Stata 14 and E-views 10 packages.

**Conclusion**

This chapter develops and presents the methodological framework suitable for conducting the study. The study employs the work of Arelleno and Bond (1991), Bundell and Bond (1995) to specify both the theoretical and empirical model.

Annual panel data on real GDP, temperature, precipitation, trade openness, FDI, REER, and inflation, gross fixed capital formation, and labor force from 2000 to 2020 are used for the study. To understand the basic features of the data, both descriptive and quantitative analyses are employed. Moreover, the system GMM estimator is employed to capture the persistent nature of economic growth and help achieve the main aim of the study. Some diagnostic tests are also carried out to ensure the consistency of the technique for estimation, such as the Hansen test, serial or autocorrelation test, stationarity test, and multicollinearity test.

Finally, the chapter makes use of the Granger-causality technique to determine whether there is a direction of causality among the variables of interest. To understand the basic features of the data, both descriptive and quantitative analyses are employed. Moreover, the system GMM estimator is employed to capture the persistent nature of economic growth and help achieve the main aim of the study. Some diagnostic tests are carried out to ensure the consistency of the technique for estimation, such as the Hansen test, serial or autocorrelation test, stationarity test, and multicollinearity test.

# CHAPTER FOUR

# RESULTS AND DISCUSSION

## Introduction

This chapter presents and discusses the estimation results. The results of the descriptive statistics of the relevant variables, the Levin-Lin-Chu (LLC) panel root tests, Im-Pesaran-Shin unit-root test (IPS), the multicollinearity test, the correlation to the relationship between the variable using the Pairwise correlations**,** the one-step and the robust two-step System GMM and Granger-causality test are presented and discussed. These results are discussed in relation to the various hypotheses of the study.

## Descriptive Statistics

These statistics provide a snapshot of the central tendency, dispersion, and shape of the distributions for each variable, allowing for a preliminary understanding of their characteristics in the dataset. The mean and standard deviation describe the average and variability of the data, while skewness and kurtosis provide information about the data's symmetry and tail behavior. Researchers can use this information to make initial assessments and decide on appropriate statistical techniques for further analysis**.**

**Table 3: Variables and Their Summary Statistics**

| Variable | Obs | Mean | Std. Dev | Min | Max | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| INF | 672 | 110.252 | 53.567 | 2.91 | 414.68 | 1.882 | 8.896 |
| FDI | 639 | 5.198 | 8.859 | -11.2 | 46.49 | 2.932 | 11.440 |
| PREP | 672 | 3.044 | 2.934 | -1.14 | 57.84 | 10.387 | 185.216 |
| GDP | 672 | 3.992 | 4.772 | -36.39 | 26.42 | -1.461 | 13.798 |
| TEM | 672 | 36.756 | 14.522 | 0.14 | 46.96 | 12.165 | 212.574 |
| URBANGRP | 672 | 4.802 | 1.311 | 1.36 | 7.68 | -0.456 | 2.979 |
| LAB | 672 | 54.915 | 4.994 | 47.18 | 70.77 | 1.518 | 5.208 |
| GCF | 672 | 21.239 | 9.586 | 0.00 | 79.40 | 1.025 | 6.703 |
| EXCH | 479 | 6.850 | 13.868 | -79.8 | 52.44 | -1.892 | 16.427 |
| TRD | 661 | 68.238 | 34.68 | 20.72 | 225.02 | 1.633 | 6.105 |
| GOVEFF | 672 | -0.6620 | 0.624 | -1.800 | 1.060 | 0.579 | 2.731 |
| CFCRP | 672 | -0.6100 | 0.621 | -1.7 | 1.230 | 0.802 | 2.880 |
| POST | 672 | -0.5790 | 0.889 | 2.840 | 1.280 | -0.086 | 2.330 |
| CLIMTEINDEX | 672 | -0.0397 | 1.4118 | -1.4257 | 18.6734 | 10.4643 | 163.935 |

**NB:** Std. Dev represents standard deviation, Min indicates minimum, Max represents maximum and Obs represents observations.

Source: Mba (2022).

The table 3 presents the descriptive characteristics of the considered variables. Of the three variables of primary interest, urbanisation revealed the smallest variation over the considered period, and for the 32 sub-Sahara African countries. Indeed, the average increase in the urbanisation of all the considered countries is 4.8%, signifying the rapid nature of urban growth across the region and are negatively skewed implying that the majority of the values are greater than their means with the minimum of 1.36% and the maximum of 7.68%.

However, this is not the case for economic growth and climate change variables. It appears that there were significant differences in the level of economic growth among sub-Sahara African countries. With an average of 3.992%, the economic growth rate of these countries was highly dispersed from the minimum of -20.6 to maximum of 26.42 over the considered period. Especially in Central Africa Republic (-20.6%) of growth rate, Zimbabwe (-17.67) of growth rate, others are Congo -10% and Mauritius -14% of growth rate. This reiterates the low growth rate of countries within the region under studies

On the climate side, rainfall variability is widely dispersed from country to country with an average of 3.044 % compared to the highly variation of temperature, of the level of 14.522 and averaged of 36.756 ºC within the period across the sample under consideration. This means that the amount of rainfall observed or measured is equivalent to 3.044% within the region. In other words, for every 100 units of the reference amount, there has been 3.044 units of rainfall. So, it indicates a relatively low or light amount of rainfall compared to the reference value.  Indeed, the average temperature values portray that countries in sub-Sahara Africa included in the sample are found in the tropics, indicating the presence of high heat in the study area. Thus, the climate index among the climate variables revealed the lowest variations over the considered period, and for the 32 sub-Sahara African countries.

**Table 4: Results of Panel Unit root test: Levin-Lin-Chu unit-root test (LLC)**

| Level | | | First Difference | | | |
|---|---|---|---|---|---|---|
| **Variables** | **LLC Statistics** | **Lag** | **Variables** | **LLC Statistics** | **Lag** | **I (0)** |
| INF | 0.5240 | 1 | D.INF | 0.0000*** | 1 | I (1) |
| FDI | 0.0000*** | 1 | D.FDI | 0.0000*** | 0 | I (0) |
| PREP | 0.0000*** | 0 | D. PREP | 0.0000*** | 0 | I (0) |
| GDP | 0.0013** | 1 | D.GDP | 0.0000*** | 1 | I (0) |
| TEM | 0.0000*** | 1 | D.TEM | 0.0000*** | 0 | I (0) |
| URBANGRP | 0.1276 | 1 | D. URBANGRP | 0.0016** | 0 | I (1) |
| LAB | 0.0055* | 1 | D.LAB | 0.0011*** | 1 | I (0) |
| GCF | 0.0002*** | 1 | D.GFC | 0.0000*** | 1 | I (0) |
| EXCH | 0.0000*** | 0 | D. EXCH | 0.0000*** | 0 | I (0) |
| TRD | 0.1396 | 1 | D.TRD | 0.0000*** | 1 | I (1) |
| GOVEFF | 0.0000*** | 1 | D. GOVEFF | 0.0000*** | 1 | I (0) |
| CFCRP | 0.0000*** | 1 | D. CFCRP | 0.0000*** | 1 | I (0) |
| POST | 0.0000*** | 1 | D. POST | 0.0000*** | 1 | I (0) |

**NB**: ***, **, * represents the rejection of the null hypothesis of nonstationary at 1%, 5%, 10% level of significance respectively, D represents the first difference, and I (0) is the lag order of integration.
Source: Mba (2022).

**Table 5: The Results of Im Pesaran-Shin Unit-Root Test**

| Level | | | | First Difference | | |
|---|---|---|---|---|---|---|
| **Variables** | **IM Statistics** | **Lag** | **Variables** | **IM Statistics** | **Lag** | **I (0)** |
| INF | 1.0000 | 1 | D.INF | 0.0000*** | 0 | I (1) |
| FDI | 0.0000*** | 1 | D.FDI | 0.0000*** | 0 | I (0) |
| PREP | 0.0000*** | 0 | D. PREP | 0.0000*** | 0 | I (0) |
| GDP | 0.000*** | 1 | D.GDP | 0.0000*** | 0 | I (0) |
| TEM | 0.0000*** | 0 | D. TEM | 0.0000*** | 0 | I (0) |
| URBANGRP | 1.0000 | 1 | D. URBANGRP | 0.0157** | 1 | I (1) |
| LAB | 0.9987 | 1 | D.LAB | 0.0350** | 1 | I (1) |
| GCF | 0.0200** | 1 | D. GFC | 0.0000*** | 1 | I (0) |
| EXCH | 0.0000*** | 0 | D. EXCH | 0.0000*** | 0 | I (0) |
| TRD | 0.4009 | 1 | D.TRD | 0.0000*** | 1 | I (1) |
| GOVEFF | 0.0022*** | 0 | D. GOVEFF | 0.0000*** | 0 | I (0) |
| CFCRP | 0.0019*** | 1 | D. CFCRP | 0.0000*** | 1 | I (0) |
| POST | 0.0000*** | 0 | D. POST | 0.0000*** | 0 | I (0) |

**NB**: ***, **, * represents the rejection of the null hypothesis of nonstationary at 1%, 5%, 10% level of significance respectively, D represents the first difference, and I (0) is the lag order of integration. Source:
Mba (2022).

From the panel unit root test results in table 5, the null hypothesis of the presence of unit root for most of the variables in their levels can be rejected since the P-values of Levin-Lin-Chu unit-root test **(**LLC) is statistically significant at any of the three conventional levels of significance with Trade (TRD), Urbanisation Growth (URBANGRP) and inflation (INF) found to be non-stationary at any of the conventional levels of significance.

But, after the first difference, these variables become stationary. This is due to the fact that the null hypothesis of the presence of a unit root (non-stationary) is rejected at 1% significance levels. On the other hand, Im-Pesaran-Shin unit-root test (IPS revealed that majority of the variables of interest were all stationary at any of the conventional levels of significance. Trade (TRD), urbanisation (URBANGRP), inflation (INF), and labor force (LAB) contain unit root hence not stationary because we failed to reject the null hypothesis that all panels contain unit root. However, all these variables become stationary after the first difference.

**Correlation Analysis**

The results from the table 6, show the correlation between the variables used in the study. Using the Pearson's correlation coefficients, it is revealed from the matrix that the correlation between the explanatory variables does not support the severe existence of the problem of multicollinearity because according to Kennedy (2008), multicollinearity is only problems when the correlation exceeds 0.80, which clearly cannot be found in the correlation matrix below. The correlation matrix reports that foreign direct investment (FDI), urbanisation growth (URBANGRP), gross capital formation (GCF), and real exchange rate (EXCH) are positively and significantly associated with GDP growth. On the other hand, trade (TRD), inflation (INF), temperature (TEM), and precipitation (PREP) are negatively and significantly associated with GDP growth.

However, government effectiveness and political stability are positively and negatively associated with GDP growth, respectively, but are both statistically insignificant. In summary, the study can conclude from the correlation matrix that foreign direct investment, urbanisation, gross capital formation, and real exchange rate capital affect GDP growth in SSA positively and significantly. On the other hand, trade, inflation, temperature, and precipitation affect GDP growth negatively and significantly in SSA.

**Table 6: Pearson Pairwise correlations**

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) GDP | 1.000 | | | | | | | | | | | |
| (2) URBANGR | 0.136 | 1.000 | | | | | | | | | | |
| | (0.000) | | | | | | | | | | | |
| (3) TEM | -0.047 | 0.096 | 1.000 | | | | | | | | | |
| | (0.222) | (0.013) | | | | | | | | | | |
| (4) PREP | 0.005 | -0.039 | -0.187 | 1.000 | | | | | | | | |
| | (0.904) | (0.318) | (0.000) | | | | | | | | | |
| (5) INF | -0.118 | -0.177 | -0.050 | 0.091 | 1.000 | | | | | | | |
| | (0.002) | (0.000) | (0.194) | (0.018) | | | | | | | | |
| (6) FDI | 0.070 | -0.082 | -0.378 | 0.188 | 0.027 | 1.000 | | | | | | |
| | (0.079) | (0.039) | (0.000) | (0.000) | (0.503) | | | | | | | |
| (7) POP | -0.113 | -0.920 | -0.108 | 0.047 | 0.058 | 0.092 | 1.000 | | | | | |
| | (0.003) | (0.000) | (0.005) | (0.227) | (0.134) | (0.020) | | | | | | |
| (8) GCF | 0.088 | -0.126 | -0.074 | 0.075 | 0.078 | 0.245 | 0.175 | 1.000 | | | | |
| | (0.022) | (0.001) | (0.055) | (0.052) | (0.043) | (0.000) | (0.000) | | | | | |
| (9) TRD | -0.078 | -0.528 | -0.117 | 0.134 | -0.112 | 0.209 | 0.575 | 0.389 | 1.000 | | | |
| | (0.046) | (0.000) | (0.003) | (0.001) | (0.004) | (0.000) | (0.000) | (0.000) | | | | |
| (10) GOVEFF | 0.003 | -0.610 | -0.047 | -0.160 | -0.057 | 0.006 | 0.666 | 0.204 | 0.296 | 1.000 | | |
| | (0.939) | (0.000) | (0.221) | (0.000) | (0.138) | (0.879) | (0.000) | (0.000) | (0.000) | | | |
| (11) CFCRP | 0.000 | -0.603 | -0.016 | -0.153 | -0.093 | 0.020 | 0.648 | 0.209 | 0.366 | 0.890 | 1.000 | |
| | (0.991) | (0.000) | (0.687) | (0.000) | (0.016) | (0.606) | (0.000) | (0.000) | (0.000) | (0.000) | | |
| (12) GOVEFF | 0.003 | -0.610 | -0.047 | -0.160 | -0.057 | 0.006 | 0.666 | 0.204 | 0.296 | 1.000 | 0.890 | 1.000 |
| | (0.939) | (0.000) | (0.221) | (0.000) | (0.138) | (0.879) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | |

Source: Mba (2022). The rejection of the null hypotheses of nonstationary is at 5%, 1% and 10% level of significant

To further assure that the model is free from the problem of multicollinearity, we use the Variance Inflation Factor (VIF) technique. Multicollinearity exists when two or more explanatory variables are related or can explain each other and are highly correlated. Multicollinearity inflates the variance of coefficients and causes type II errors, leading to unreliable estimates. If the variance inflation factor for each variable is below 10, then there is no multicollinearity, however, if the VIF is above 10, then there is the problem of multicollinearity (Michael H et al., 2005). The table 7 reports the variance inflation factor, where it is clearly observed that the VIF for each independent variable is below five, confirming that there is no multicollinearity and analysis based on the variables is reliable.

**Table 7: Variance Inflation Factor (VIF)**

| VARIABLE | VIF |
|---|---|
| URBANGRP | 3.23 |
| GOVEFF | 3.13 |
| POST | 2.54 |
| TRD | 2.31 |
| GCF | 1.53 |
| INF | 1.24 |
| FDI | 1.20 |
| TEM | 1.18 |
| PREP | 1.13 |
| EXCH | 1.12 |
| CFCRP | 6.84 |

Source: Mba (2022).

**Granger Causality Tests**

In order to determine the direction of causality between temperature, precipitation, and urbanisation in sub-Saharan Africa, a Granger causality test is applied to measure the linear causation among the variables.

Employing the Pairwise Granger causality test attributed to Engel and Granger (1987), the following results are obtained as shown in the table 8: In testing for causality between variables, the following outcomes can be expected: A test concludes that a variable Granger causes the other when the set of coefficients for the two variables are statistically significant. So, it is reasonable to suppose that causality shifts from one variable to another. On the other hand, when the set of coefficients on the variables is not statistically significant, a test shows that one variable does not cause the other.

**Table 8: Outcomes of Pair-wise Granger Causality Tests**

| Hull Hypothesis | F-Statistics | Probability |
|---|---|---|
| URBANGRP does not Granger Cause GDP | 11.5555 | 0.0007*** |
| GDP does not Granger Cause URBANGRP | 0.01571 | 0.9003 |
| PREP does not Granger Cause GDP | 2.03294 | 0.0421** |
| GDP does not Granger Cause PREP | 0.47479 | 0.6349 |
| TEM does not Granger Cause URBANGRP | 0.24326 | 0.6220 |
| URBANGRP does not Granger Cause TEM | 4.91029 | 0.0270** |
| PREP does not Granger Cause URBANGRP | 1.72276 | 0.1898 |
| URBANGRP does not Granger Cause PREP | 0.41186 | 0.5213 |
| TEM does not Granger Cause GDP | 2.84550 | 0.0921* |
| GDP does not Granger Cause TEM | 2.17300 | 0.1409 |

**NB**: ***, **, and * represent significance level at 1%, 5% and 10% respectively

Source: Mba (2022).

The table 8 presents the results of the granger causality between the variables of primary interest in the study. From the table, the null hypothesis that urbanisation does not granger causes economic growth is statistically significant, this suggests that urbanisation is the cause of economic growth in the SSA. Thus, urbanisation is relevant in explaining the variations in economic growth. On the other hand, the null hypothesis of GDP does not cause urbanisation is not rejected, indicating that GDP is not the cause of urbanisation in SSA. Therefore, GDP do not aid in explaining the variations in urbanisation. However, this indicates a unidirectional causality from urbanisation to economic growth. This result is in line with (Zhao & Wang, 2015; Shahbaz et al. 2014, Barido & Marshall, 2014) who found a one-way relationship between urbanisation and economic growth.

Furthermore, at a 5% significance level, the results support rejection of the null hypothesis that precipitation does not cause GDP growth. However, the null hypothesis that real gross domestic product (economic growth) does not cause precipitation is not rejected, implying that economic growth is not the cause and thus, economic growth does not aid in explaining the variations in precipitation. Thus, there is a unidirectional causality from precipitation to economic growth. This result is contrary to the findings of Marshall (2014) who discovered no direction of causality between precipitation and economic growth

Additionally, the results above show that the null hypothesis that temperature (TEM) does not cause GDP growth is rejected at 10 percent level. This means that temperature causes GDP growth. It implies that the lag values of temperature together with the lag values of GDP or economic growth help in explaining the variations in economic growth better than lag values or the history of economic growth. On the other hand, the null hypothesis of GDP Granger causes temperature is not rejected, indicating that the lag values or the history of GDP together with the lag values of temperature do not aid in explaining the variations in temperature. Thus, a unidirectional causality between temperature and economic growth is found. This is an indication that temperature is a very important variable in achieving economic growth in sub-Saharan Africa. This result is consistent with the results find by Zhao and Wang (2015) who found that there is unidirectional causality between temperature and economic growth

Besides, the Granger causality test indicates that the null hypothesis that urbanisation does not cause temperature (TEM) can be rejected, implying that urbanisation does cause temperature since the coefficient resulting from the test is statistically significant. However, the null hypothesis that temperature does not cause urbanisation cannot be rejected, meaning that temperature does not cause urbanisation since the resulting coefficient from the test is not statistically significant, implying that the lag values of temperature together with that of urbanisation do not predict variations in urbanisation. At a 5% significance level, a unidirectional causality running from urbanisation to temperature has thus been identified as found by Zhao and Wang (2015) who found that there is unidirectional causality between urbanisation and temperature growth.

Finally, from the Granger causality test in table 8, the null hypothesis of precipitation does not Granger cause urbanisation cannot be rejected due to the fact that the p-value is bigger than any of the conventional levels of significance, meaning that precipitation does not cause urbanisation. This indicates that the lag values or the history of precipitation together with the history of urbanisation does not aid in explaining the variations in precipitation. On the other hand, the null hypothesis of urbanisation does not cause precipitation cannot also be rejected, meaning that urbanisation does not cause precipitation. This result is consistent to the study of Barido and Marshall (2014) who found no causal relationship between urbanisation and precipitation.

The study concludes that there is no direction of causality between precipitation and urbanisation. Thus, there is directional causality between temperature, precipitation, urbanisation, and economic growth and it is unidirectional.

**The Effect of Climate Change and Economic Growth in SSA**

To estimate the short-run relationships between climate change and urbanisation on economic growth in the region, the robust two-step system GMM was employed to capture the persistent nature of economic growth and address the problems of omitted variables, measurement error, endogeneity, and country-specific heterogeneity.

The short-run estimates based on the two-step system GMM estimations strategies are reported in each column of table 9. below. The autocorrelation test results indicate that there is no autocorrelation of the highest order. Also, the Hansen test results suggest that the instruments are valid, that is uncorrelated with the error term. The table 9 presents four alternative models. In model 1, we present the results of temperature on growth without accounting for possible non-linearity. Model 2, included a quadratic term of temperature in order to account for the possibility of non-linearity and the consequent threshold effect of temperature on economic growth in the sub-Sahara region.

In model 3, we present the estimates of precipitation on growth without accounting for the possibility of non-linearity. However, in model 4, we showed results of the effect of precipitation on growth including the quadratic term to account for the possibility of non-linearity and the consequent threshold effect of precipitation on economic growth in the region.

**Table 9: The effect of Climate Change and Economic Growth in SSA**

| VARIABLE | MODEL 1 | MODEL 2 | MODEL 3 | MODEL 4 |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| $GDP_{r-1}$ | 0.0740*** | 0.0720*** | 0.1219*** | 0.0620*** |
| | (0.0070) | (0.0040) | (0.0210) | (0.0010) |
| TEM | 0.0005* | 1.7350*** | 0.0049 | 0.0010*** |
| | (0.0003) | (0.4000) | (0.030) | (0.0004) |
| $TEM^2$ | | -0.0280*** | | |
| | | (0.0101) | | |
| PREP | 0.0300*** | 0.0360*** | 0.9030*** | 0.0950*** |
| | (0.0050) | (0.0050) | (0.0188) | (0.0200) |
| $PREP^2$ | | | | -0.0010*** |
| | | | | (0.0003) |
| GOVEFF | 0.5510** | 5.7500** | -4.1376** | 0.9380** |
| | (0.2220) | (0.1860) | (1.8791) | (0.3920) |
| POST | 0.4870*** | 0.6000*** | 1.8896*** | 0.6090*** |
| | (0.0700) | (0.1390) | (0.5261) | (0.0850) |
| TRD | -0.0300*** | -0.1100*** | -0.0140 | -0.0140 |
| | (0.0010) | (0.0020) | (0.0128) | (0.0010) |
| GCF | 0.0787*** | 0.3040*** | 0.1027*** | 0.1320*** |
| | (0.0182) | (0.1070) | (0.0218) | (0.0560) |
| FDI | 0.0180* | 0.0390 | 0.0388*** | 0.0130*** |
| | (0.0020) | (0.1260) | (0.0083) | (0.0030) |
| INF | -0.0080*** | -0.0080*** | -0.0257*** | -0.0090*** |
| | (0.0010) | (0.0010) | (0.0018) | (0.0010) |
| LAB | 0.0780*** | 0.0720*** | 0.2909*** | 0.1060*** |
| | (0.1091) | (0.0120) | (1.0238) | (0.0160) |
| CFCRP | -0.2240 | -0.1940 | -0.6484 | -0.0270 |
| | (1.5900) | (0.4870) | (1.4418) | (0.2590) |
| CONSTANT | -2.9820*** | -9.3237*** | -12.383*** | -4.3550*** |
| | (5.7919) | (1.2452) | (5.1715) | (0.8970) |
| Number of Obs | 672 | 672 | 672 | 672 |
| Time Dummies | YES | YES | YES | YES |
| No. of instr. | 29 | 29 | 29 | 29 |
| F. Statistics | 0.000 | 0.000 | 0.000 | 0.000 |
| AR (1) | 0.0017 | 0.0054 | 0.0018 | 0.0056 |
| AR (2) | 0.2351 | 0.2480 | 0.2599 | 0.2545 |
| Hansen test | 0.8662 | 0.7944 | 0.9365 | 0.8905 |

NB: ***, ** and * represent significance level at 1%, 5% and 10% respectively. Standard Errors are in parenthesis
Source: Mba (2022)

The estimate results revealed the anticipated short-run relationships between temperature and economic growth. Without accounting for the possibility of the non-linearity, the results in model 1 revealed that the lag of the GDP Growth as a proxy for economic growth is positive and statistically significant at 1% level, evidencing the persistency of economic growth in the region.

This means that the previous year economic growth is relevant in explaining current economic growth. The past GDP growth is a strong predictor of its current level. This indicates that GDP growth tends to be somewhat path-dependent, which suggests that a country's GDP growth in the present year has a strong influence in determining her level of growth in the following year. The estimated coefficient of (0.0740) implies that previous GDP would increase current GDP by (0.0740).

The results also revealed that temperature is a very important predictor of growth within the sub-Sahara region. The effect of temperature on GDP growth was found to be positive (0.0005). The coefficient for temperature is statistically significant at 1 percent level. This signifies that in the short-run, temperature has positive effect on economic growth. Specifically, a percentage increase in temperature will significantly improve economic performance in the sub-Sahara region by approximately 0.0005, ceteris paribus. Warmer temperatures can extend the growing seasons and enhance agricultural productivity. In SSA, where agriculture often plays a crucial role in the economy, increased temperatures may allow for multiple crop cycles per year, leading to higher yields and increased food production. This can boost both agricultural income and food security, contributing to economic growth.

In regions with cooler climates, households and businesses often use energy for heating during colder seasons. In SSA, higher temperatures can reduce the need for heating, potentially leading to energy cost savings for households and businesses, which can be redirected to other economic activities

The result is contrary with both empirical and theoretical studies including the following authors Odusola & Abidoye (2012); Dell et.al. (2008); Fankhauser & Tol (2005); Lanzafame (2012); Dell et.al. (2009); Nordhause (2006); Tol (2018) and many others who also found temperature to have a negative impact on GDP growth. This may be because higher temperatures can also have negative consequences, such as droughts, heat stress, or reduced agricultural yields. These adverse effects might offset the positive impacts in the short term.

Including the quadratic term of temperature, rendered the coefficients of the temperature still statistically significant and negatively affect economic growth in the region in model 2. The coefficient of the quadratic term of temperature is negative and statistically significant meaning that the effect of temperature on economic growth is non-linear. This implies that an increase in temperature improve economic growth significantly to some level and thereafter will be detrimental to economic growth. The optimal value of temperature is 31% (See Appendix). Beyond temperature level 31%, temperature gradually reduces economic growth within the region. This empirical findings is consistent with previous studies done by Alagidede et al.(2014) who discovered a non-linear relationship between temperature and economic growth in both the short-run and long-run estimation.

Better still temperature is very relevant in improving economic performance, but only to some point, after which its effect is detrimental to growth in the region. This suggest that, beyond a certain threshold level of average temperature, increase in temperature reduces economic growth all things being equal. Given that sub-Sahara Africa relies hugely on agriculture sector for the bulk of the economic output, we surmise that temperature could actually reduce agricultural output with ramification for industrial growth, job creation, discomfort as a result of heat, outbreak of temperature induced sickness, failure of some technology due to heat stress and poverty reduction efforts if temperature in the region goes beyond 31-degree census.

In model 3, the results further revealed the importance of precipitation on economic performance in the SSA region. Without accounting for the quadratic term of precipitation, the results showed that precipitation is a relevant indicator of economic performance in the SSA region. At 1% level, precipitation coefficient is positive and statistically significant. This signifies that a 100mm increase in rainfall will improve economic growth in the region by 0.095. Though water is a scarce economic resource, having more of this good in an economy is generally a plus for agricultural productivity providing job opportunities for most youth in the region as well as raw materials for industrialization. Electricity, now one of the instrumental entities for economic growth is generated by using water, precipitation is also a source of drinking water most region in SSA. Thus, rainfall enhances production and the supply chain, hence affecting economic performance in SSA, especially when the region agriculture productivity is the mainstream for economic growth. The result is consistent with the findings by Lanzafame (2012); Lanzafame (2014); Odusola and abidoye (2015); Sequeire et al. (2018) Alagidede, Adu and Frimpong (2015) who all discovered that rainfall positively influence economic growth.

However, in model 4, we included the quadratic term of the precipitation to account for possibility of non-linearity. The coefficient of the quadratic term of the precipitation is negative and statistically significant meaning that the effect of precipitation on economic growth is non-linear. This means that increase in precipitation will promote economic performance in the region to some level and after that it becomes detrimental to economic growth in the SSA region. The maximum value of precipitation is 48 millimeters (See appendix). Beyond this level, precipitation gradually hinders economic growth within the region. Thus, as the rainfall level exceed this threshold 48mm, economic growth reduces. The study is consistent with results found by Sequeire et al. (2018); Alagidede, Adu and Frimpong (2015) who discovered that precipitation have a non-linear relationship with economic growth.

Alternatively, precipitation is beneficial to economic performance, but only to some point, after which its effect is detrimental to growth in the region. This empirical study is inconsistent with previous studies such as Alagidede et al. (2014) who discovered a non-linear but statistical insignificant relationship between precipitation and economic growth both in the short and long run.

The study also revealed the relevance of some determinants of economic growth in the region. Political stability (POST) has a positive impact on economic growth. Its coefficient of 0.487 suggests that political stability is very relevant in explaining economic growth in sub-Saharan Africa. A unit increase in political stability leads to an approximately 0.487 increase in economic growth at 1 percent level of significance. The positive effect of POST emphasizes the fact that sub-Saharan African countries need peace to foster economic growth and reduce poverty.

Besides, the results revealed that the coefficient of labor force (LAB) is positive and statistically significant, signaling a positive influence on economic growth. Labor force is positive and significant at 1 percent with a coefficient of 0.078 indicating an increase in economic growth by an amount of 0.078 if there is a unit increase in the labor force (LAB). This is consistent with the argument of Jayaraman and Singh (2007) and Ayibor, 2012) who asserted that there can be no growth achievement without the involvement of labour as a factor input hence, the positive and significant coefficient. This result however contradicts the works of Frimpong and Oteng A. (2006), and Sakyi (2011) who found a negative effect of labour on economic growth.

Moreover, from the result, it can be revealed that foreign direct investment (FDI) exerts a positive influence on economic growth. Its coefficient of 0.018 suggests that, an increase in FDI leads to approximately 0.02 increase in economic growth at 1 percent level of significance. The positive effect of FDI emphasizes the fact that sub-Saharan African countries have benefited positively from the spillover effect of foreign investors in the region. The study is consistent with the work of De Mello (1997) who argued that FDI influences economic growth by serving as an important source of capital, which complements domestic private investment in developing productive capacity. The finding is line with the findings of Shaheen et al., (2013); Falki (2009) and Khan and Qayyum (2007). It is also consistent with conclusions reached by Ibrahim (2011) and Asiedu (2013) in the case of Ghana. Ibrahim (2011) and Asiedu (2013) found positive and statistically significant effect of FDI on economic growth for Ghana

In addition, the results show that inflation as a measure of macroeconomic stability is relevant in explaining GDP growth in SSA. At 1% inflation (INF) is statistically significant. There is a negative effect of instability on GDP growth; hence, an increase in inflation reduces economic growth in SSA by 0.008. That is, economic instability discourages GDP growth in SSA due to the high uncertainty that dampens investment and economic activity. In the empirical literature the results support the findings by Gokal and Hanif (2004) Ahmed and Mortaza (2005), Mallik and Chowdhury (2001) Samimi and Shahryar (2009) Bittencourt (2010) and Gylfason (1999). Gylfason (1999) found evidence in support of a negative effect of inflation on economic growth in the short run for countries that export primary commodities

Again, the coefficient of trade openness (TRD) of -0.03 indicates that if sub-Saharan African countries were to increase their trade openness by one percent, economic growth would decrease by approximately 0.03 percent. This is an indication that, the region depends more on import than export. The results obtained in this study in the short run does not absolutely resolve the conflicting results in the extent literature but contribute to the controversy in the literature by aligning itself with those studies such as Dollar and Kraay (2003), Sarkar (2008), Ali and Abdullah (2015) and Falki (2009) which believe that trade openness positively affects real GDP in the short run.

Finally, to the foregoing, the coefficient of Gross Capital Formation (GCF) is statistically significant at 1% level of significant, indicating that if capital in the region is increased by one-unit, economic growth in SSA countries would increase approximately by 0.0787. This means that Capital in very important in determining economic growth in most developing countries especially SSA. The finding is line with the findings of Shaheen et al., (2013); Falki (2009) and Khan and Qayyum (2007). It is also consistent with conclusions reached by Ibrahim (2011) and Asiedu (2013) in the case of Ghana

**Effect of Climate Change on Economic Growth**

The short -run results based on the two-step system GMM estimations technique is reported in each column of the Table 10. The table presents two alternative models. In model 1, we present the results of Climate Index on growth without accounting for possible non-linearity. In model 2, we included a quadratic term of Climate Index in order to account for the possibility of non-linearity and the consequent threshold effect of Climate Index on economic growth in the sub-Sahara region. The results as presented in Table 10 indicate that using climate change index to capture climate change provide an improved effect compared to the individual variables notably temperature and precipitation.

The coefficient of climate index is statistically significant and negatively affects economic performance in the region. This implies that, if climate changes by a unit, it would reduce economic growth in the region by approximately 0.3 percent.

The results as presented in model 2 revealed that, the coefficient of the quadratic term of the climate change index is positive and statistically significant at 5% level of significance. This implies that the quadratic term of climate index is very important in explaining economic growth in the region. The results also indicate that the effect of climate change on economic growth is non-linear. Increase in climate change will reduce economic performance significantly to some level and thereafter will be beneficial to economic growth.

The minimal value of climate change is 28 degrees Celsius (refer to appendix). Beyond this level, climate change index gradually promotes economic performance.

**Table 10: Effect of Climate Change Index on Economic Growth.**

| VARIABLE | MODEL 1 | MODEL 2 |
|---|---|---|
| GDP $_{r-1}$ | - 0.2873*** | - 0.5180*** |
| | 0.0069) | (0.0050) |
| CLIMATEINDEX | -0.3208*** | -1.6900*** |
| | (0.1295) | (0.3870) |
| CLIMATEINDEX $^2$ | | 0.0300*** |
| | | (0.0100) |
| GOVEFF | -5.6223 | 6.9010** |
| | (3.1890) | (3.1160) |
| POST | 2.0945*** | -3.4680 |

| | | |
|---|---|---|
| | (0.7039) | (1.9300) |
| TRD | -0.0563 *** | -0.0650 *** |
| | (0.0089) | (0.0280) |
| GCF | 0.0768*** | -0.1430*** |
| | (0.0155) | (0.0430) |
| FDI | 0.0405*** | 0.0720** |
| | (0.0091) | (0.0340) |
| INF | -0.0222*** | -0.0140*** |
| | (0.0022) | (0.0050) |
| LAB | 0.3043*** | 1.4010*** |
| | (0.0792) | (0.2000) |
| CFCRP | -1.2061 | 8.2300 |
| | (1.1607) | (2.6680) |
| CONSTANT | -15.3774** | -6.6740 |
| | (5.5909) | (4.1550) |
| Number of Obs. | 672 | 672 |
| Time Dummies | YES | YES |
| Number of instr. | 29 | 29 |
| F Statistics | 0.000 | 0.000 |
| AR (1) | 0.0018 | 0.0056 |
| AR (2) | 0.2599 | 0.2545 |
| Hansen test | 0.9365 | 0.8905 |

**NB:** ***, **, and * represent significance level at 1%, 5% and 10% respectively
Standard Errors are in parenthesis
Source: Mba (2022).

**The effect of Urbanisation on Economic Growth in SSA**

Table 11 presents the results of urbanisation on economic growth. Model 1 presents the direct effect of urbanisation on growth, model 2, presents the direct effect of climate change index on economic growth, model 3 and 4 present the moderating effects of urbanisation on economic growth, model 5 presents the moderation effect of climate change index on urbanisation – growth relationship and model 6 captures the threshold effect of urbanisation on economic growth in SSA.

**Table 11: Effect of Urbanisation on Economic Growth In SSA**

| VARIABLE | MODEL 1 | MODEL 2 | MODEL 3 | MODEL 4 |
|---|---|---|---|---|
| GDP $_{r-1}$ | -0.034*** | -0.0640** | -0.0020 | -0.5040*** |
| | (0.0180) | (0.0300) | (0.0140) | (0.0070) |

| | | | | |
|---|---|---|---|---|
| URBANGRP | 0.5290*** | 0.4540** | -1.3120 | -1.2270*** |
| | (0.2920) | (0.2030) | (2.6500) | (0.6600) |
| TEM | -0.0020* | | 1.1790** | -0.0200** |
| | (0.0010) | | (0.5340) | (0.0100) |
| PREP | -0.2830** | | -0.0810*** | -1.6750** |
| | (0.1400) | | (0.0230) | (0.7710) |
| CLIMATEINDEX | | -0.0450*** | | |
| | | (0.0070) | | |
| URBANGRP*TEM | | | -0.0020*** | |
| | | | (0.0010) | |
| URBANGRP*PREP | | | | -0.0350*** |
| | | | | (0.0100) |
| GOVEFF | 1.6260** | 2.1150*** | 1.9540 | 0.7240 |
| | (0.7280) | (0.6620) | (1.9540) | (3.373) |
| POST | 0.3950 | 0.3840 | 1.1010** | 0.4880 |
| | (0.7230) | (0.3840) | (0.5220) | (0.8820) |
| TRD | -0.0050*** | 0.0060* | -0.0190*** | -0.0060 |
| | (0.0030) | (0.0040) | (0.0060) | (0. 0170) |
| GCF | 0.0680*** | 0.0730*** | 0.0770*** | 0.0550 |
| | (0.0150) | (0.0080) | (0.0100) | (0.0560) |
| FDI | 0.094* | 0.1600 | 0.0405*** | -0.0063 |
| | (0.0081) | (0.0110) | (0.0091) | (0.0218) |
| INF | -0.0281*** | -0.0200*** | 0.0222*** | -0.0264*** |
| | (0.0025) | (0.0030) | (0.0120) | (0.0038) |
| CFCRP | -2.0590 | -1.8680*** | -3.1060 | 0.6690 |
| | (1.6300) | (0.3400) | (1.9500) | (3.8780) |
| CONSTANT | -3.9990*** | -3.5880*** | 0.4040*** | -5.7060 |
| | (1.002) | (1.3500) | (2.3720) | (4.9750) |
| Number of Obs. | 672 | 672 | 672 | 672 |
| Time Dummies | YES | YES | YES | YES |
| Number of instr. | 29 | 29 | 29 | 29 |
| F Statistics | 0.000 | 0.000 | 0.000 | 0.000 |
| AR (1) | 0.0016 | 0.0055 | 0.0018 | 0.0052 |
| AR (2) | 0.2936 | 0.2564 | 0.2172 | 0.1195 |
| Hansen test | 0.9146 | 0.8921 | 0.9703 | 0.9271 |

**Continuation of table 11**

**Effect of Urbanisation on Economic Growth In SSA**

| VARIABLE | MODEL 5 | MODEL 6 |
|---|---|---|

| | | |
|---|---|---|
| GDP $t_{-1}$ | -0.418*** | 0.578*** |
| | (0.0290) | (7.5970) |
| URBANGRP | 2.3160*** | 14.683* |
| | (9.8810) | (2.650) |
| TEM | | 0.461*** |
| | | (0.1350) |
| PREP | | -0.0510 |
| | | (0.1820) |
| CLIMATEINDEX | | 1.675*** |
| URBANGRP*CLIMATEINDEX | (0.7710) | (0.2130) |
| | 0.2770 | |
| **URBANGRP$^2$** | | -0.221*** |
| | (0.1101) | (0.8380) |
| GOVEFF | -0.3630 | 8.0390 |
| | (2.5760) | (6.3310) |
| POST | 0.6520 | -12.8*** |
| | (0.6700) | (3.5060) |
| TRD | -0.028*** | -0.0140 |
| | (0.0060) | (0.0390) |
| GCF | -0.062*** | -0.0520 |
| | (0.0120) | (0.0620) |
| FDI | -0.0140** | 0.040*** |
| | (0.0060) | (0.0091) |
| INF | -0.023*** | 0.022*** |
| | (0.0020) | (0.0120) |
| CFCRP | -0.2160 | -3.1060 |
| | (2.1800) | (1.9500) |
| CONSTANT | 7.7260 | 0.404*** |
| | (4.905) | (2.3720) |
| Number of Obs. | 672 | 672 |

| | | |
|---|---|---|
| Time Dummies | YES | YES |
| Number of instr. | 29 | 29 |
| F Statistics | 0.000 | 0.000 |
| AR (2) | 0.2351 | 0.2599 |
| Hansen test | 0.8662 | 0.9365 |

Source: Mba (2022)

In model 1 of table 11, the results revealed that, Urbanisation is very relevant indicator of economic growth in the sub- Sahara region. The coefficient of urbanisation is positive (0.5290) and statistically significant at the 1% level. If urbanisation in sub-Saharan African countries were to increase by 1 percent, then economic growth in the region would have risen by approximately 0.53 all things being equal. This empirical finding is consistent with Hossai (2011); Zhao and Wang (2015); Todaro and Haris (1970); Lewis (1954) among others, who discovered a favorable association between economic growth and urbanisation**,** However, the results is contrary to Fay and Opal (2000); Arouri et al. (2014); Lewis (2014); Bloom et al. (2008); Shabu (2010) who discover a negative association between urbanisation and economic growth.

Urbanisation has traditionally been regarded as a boon to many economies that benefit from the implicit inputs of production, in this case labor, in large and inexpensive amounts. As a result of the structural transformation process, labour boosts the overall productivity of the economy. This is especially true in the reallocation of resources between regions and sectors, one of the most important characteristics of which is the migration of labour from agricultural to the industrial sector. For a long time, the structure of the economy as a result of rural migration has had a beneficial effect on the pace of urban expansion, which is a factor of economic growth for the economy. Hossai

(2011); Zhao and Wang (2015); Todaro and Haris (1970); Lewis (1954) among others, who discovered a favorable association between economic growth and urbanisation

The results from model 2 indicate that climate index is relevant in explaining economic growth in the region. The coefficient of the climate index is negative and statistically significant 1% level. However, a unit increase in climate change index will reduce economic growth by 0.045.

In model 3 and 4, the results revealed that temperature and precipitation are significant in explaining the effect of urbanisation on economic growth. Because the coefficient for interacting temperature with urbanisation and precipitation with urbanisation to capture the moderating role of these climate change variables on urbanisation- economic growth relationship and are all statistically significant even at 1 percent. The result is contrary to Fay and Opal (2000); Arouri et al. (2014); Lewis (2014); Bloom et al. (2008); Shabu (2010) who discover a negative association between urbanisation and economic growth.

To discuss this result, we need to evaluate the partial effect to examine how precipitation moderate the effect of urbanisation on economic growth. The coefficient of the interaction term is negative and statistically significant in explaining urbanisation and economic growth relationship. However, with the average rainfall of 3.044, a rise in Urbanisation will reduce economic performance by approximately 1.3335(refer to appendix). This implies that, a percentage increase in Urbanisation will decrease economic performance in the region by approximately 1.3335 percent given the average rainfall of 3.044. This therefore shows that precipitation once increased has a significant impact on growth as both a variable on its own and negatively influencing urbanisation hinder economic growth (Lewis,2014; Bloom et al. 2008) whose studies discovered that precipitation is very integral in the determining economic growth.

Also, rainfall can further aggravate the already existing problem in the urban areas. An increase in precipitation within the urban setting can lead to severe flooding and sanitation issues and this can post serious health problems such as the outbreak of diseases and sanitation problems, including risk of human life, damage to commercial buildings and infrastructure and loss of crops and livestock as well as disrupt transport and communication and these can have detrimental implications on economic performance in the region as more resources are geared towards addressing these problems instead of developmental projects that will propel growth (Lewis,2014; Bloom et al. 2008)

Again, we also presented the results of the interaction term of Urbanisation with temperature accounting for moderating effect of temperature in the urbanisation growth relationship. The results revealed that Urbanisation interacting temperature is very important in predicting economic performance in the SSA region. The coefficient of the interaction term is negative and statistically significant even at 1 percent. Again, estimating the moderating role of temperature on urbanisation, we need to evaluate the partial effect. Thus, with an average temperature of 36.756 degree Celsius taking from descriptive statistics, a rise in Urbanisation will reduce economic performance by approximately 1.3855. This indicates that temperature reduces the effect of urbanisation on economic growth by 1.3855 (refer to appendix)

An increase in temperature in the urban areas can affect the life of city dwellers, causing wide spread of discomfort, respiratory problems including the outbreak of tropical diseases, sunstroke, dehydration, tiredness and increasing mortality rate due to heatstroke. All these health problems coupled with the implied congestion in the urban areas would increase public spending on water supply, sanitation, school, healthcare centers and transportation rather than creating wealth. This result is consistent with studies in European countries of Brulhart and Sbergami (2009), who found that urban agglomeration supports economic growth up to a certain level of development, then the diseconomies effect impedes economic growth

The results in model 5 shows that climate change index is statistically significant in determining economic growth in the region. This is because we reject the null hypothesis at any of the conventional level of significance. Thus, an increase in climate change index is associated with a decrease in economic growth in the region. However, interacting climate change index with urbanisation, the coefficient of the interacting term is negative and statistically insignificant in explaining the effect of urbanisation and economic growth.

However, in model 6, the coefficient of the urbanisation square is negative (-0.2210) and statistically significant at 1% level. This implies that the effect of urbanisation on economic growth was shown to be non-linear. The results further reveal that Urbanisation enhances economic performance to some point after that, it becomes detrimental to economic growth. This result is consistent with Nguyen (2014) and other studies in European countries of Brulhart and Sbergami (2009), who found that urban agglomeration supports economic growth up to a certain level of development, then the diseconomies effect impedes economic growth. The maximum value is 33% (refer to appendix). Below this level urbanisation gradually enhanced economic performance.

The study further reveals the relevance of international trade, gross fixed capital formation, inflation and foreign direct investment in determining economic growth within the SSA region in model 1. The results revealed that the coefficient of trade (TRD) is negative (-0.005) and statistically significant, signaling a negative influence on economic growth. This implies that opening up our borders for trade activities reduces economic growth because most of the countries within the region import more than export.

Moreover, from the result, it can be revealed that foreign direct investment (FDI) exerts a positive influence on economic growth. Its coefficient of (0.094) suggests that, a unit increase in FDI leads to approximately 0.09 increase in economic growth at 1 percent level of significance.

Macroeconomic stability is very important in every economic activity. GDP growth is also influenced by the level of macroeconomic stability. The results show that inflation as a measure of macroeconomic stability is important in explaining GDP growth in SSA. At a 1% significance level, inflation (INF) is statistically significant. There is a negative (-0.0281) effect of instability on GDP growth, meaning economic instability discourages GDP growth in SSA due to the high uncertainty that dampens investment activity.

Our findings are consistent with (Gokal and Hanif, 2004; Ahmed and Mortaza, 2005; Mallik and Chowdhury, 2001; Samimi and Shahryar, 2009; Bittencourt, 2010; and Gylfason, 1999) and Gylfason (1999) who found evidence in support of a negative effect of inflation on economic growth in the short run. The coefficient of Gross Capital Formation as a proxy for capital is positive (0.068) and statistically significant at the 1% level, indicating that if capital increases by 1%, economic growth increases by 0.07%.

**Chapter Summary**

The chapter analyzes the effect of urbanisation and climate change (variables) on economic growth in Sub-Saharan Africa (SSA). The analysis of the factors influencing economic growth in SSA highlights the complexity and interconnectedness of various elements. Climate factors, such as temperature and precipitation, have direct implications for agricultural productivity, which remains a crucial sector in many SSA economies. Urbanisation, when effectively managed, can contribute to economic growth, but inadequate planning can lead to challenges that hinder development. Inflation, FDI, trade, exchange rate, and labour force also play crucial roles in driving economic growth.

# CHAPTER FIVE

# SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

**Introduction**

The purpose of this chapter is to present the summary, conclusions and some policy recommendations based on the findings of the study. The chapter also offers some directions for future research in the area of climate change and urbanisation on economic growth.

**Summary**

The objective of the study was to examine the effect of urbanisation and climate change on economic growth in Sub-Saharan Africa. Specifically, the study investigates the non-linear association between urbanisation and economic growth, the moderation role of precipitation in the urbanisation – growth relationship, the moderation role of temperature in the urbanisation – growth relationship and the intensity of climate change variables and economic growth.

In order to achieve the objectives, the study employed the system GMM technique developed by Blundell and Bond (1998) to examine short-run dynamics among the variables used in the estimation. The explanatory variables used in the study were gross domestic product per capita, real effective exchange rate, trade openness, foreign direct investment, inflation, government effectiveness, labour force, political stability, control for corruption and gross fixed capital formation. All the tests and estimations were conducted with the help of Stata 14 and E- views 10 packages.

Before estimating the model, panel time series characteristics of data were tested using the Levin-Lin-Chu (LLCF) and Im Pesaran- Shin test statistics. The unit roots results suggested that all the variables were stationary but there were made of mixture of variables integrated at I (0) and I (1). The study then proceeded to examine the effect of climate change and urbanisation on growth in SSA.

The following are the main findings of the study in relation to the objectives:

- The results of the short run estimates revealed that in the short run, temperature and precipitation exerted statistically significant effect on economic growth in SSA. An increase in precipitation is associated with a rise in economic growth by 0.095. Thus, including the quadratic term of precipitation, the results show that the effect of precipitation on economic growth is non-linear. However, as the precipitation level exceed the threshold of 48%, economic growth reduces.
- However, including the quadratic term to temperature, the results shows that temperature promote economic performance to some point and become detrimental to economic growth within the region confirming the non-linearity between economic growth and temperature. Thus, as the temperature level exceeds the threshold of 31degree Celsius, economic growth reduces.
- Urbanisation, was found to enhance economic performance in the region. An increase in urbanisation is associated with a rise in economic growth by approximately 0.53. Urbanisation has traditionally been regarded as a boon to many economies that benefit from the implicit inputs of production, in this case labor, in large and inexpensive amounts. As a result of the structural transformation process, labour boosts the overall productivity of the economy. This suggested that, precipitation, temperature and Urbanisation serve as a catalyst for economic growth in sub-Saharan African countries.
- The coefficient of climate change index was revealed to be negative and statistically significant. A unit increase in climate change index will reduce economic growth by 0.03208. Including the square of climate

change index, the coefficient becomes positive and statistically significant. This means that the effect of climate change index on economic growth is non- linear. However, climate change index reduces economic growth to certain point after that it becomes economic growth enhancing. The minimum value of climate index estimated was 28 degrees Celsius beyond which climate change index become beneficial to growth.

- Urbanisation on the other hand was discovered to have a non-linear relationship with economic growth. This implies that urbanisation promote economic growth up to a certain level and begins to slums economic performance. The threshold was estimated to be 33% beyond which urbanisation becomes detrimental to growth.
- Considering the moderating role of temperature and precipitation on the urbanisation – economic growth relationship, it was found that the coefficient of the interacting terms was negative and statistically significant. This means that temperature and precipitation are very relevant in explaining the effect of urbanisation on economic growth. The study discovered that, with the average precipitation of 3.044 millimeters, an increase in precipitation reduced the impact of urbanisation on growth by 1.3335 percent. Precipitation once increased has a significant impact on growth as both a variable on its own and negatively influencing urbanisation hinder economic growth. However, the moderating role of temperature on urbanisation was also found to be significant in determining growth. With the average temperature of

36.756, for every 1-degree Celsius rise in temperature, reduces the effects of urbanisation on growth by 1.4.

- Climate change index also played a significant in determining economic growth in the region. Thus, interacting climate change index with urbanisation, it become insignificant in moderating the effect of urbanisation on growth in the region. however, the climate change index also exhibits a non-linear relationship.
- The short run dynamic estimates further revealed that foreign direct investment exerted a positive and statistically significant influence on economic growth in the short run. This emphasizes the crucial role that FDI plays in the growth process of SSA, inflation was shown to be negative and statistically significant on economic growth. Thus, macroeconomic stability is important in determining economic performance as a stable macroeconomic environment is conducive for production and investment, the effect of labor force (LAB) on economic growth was discovered to be statistically significant and positive. It also emphasises the important role that labor force plays in the growth process of SSA. This finding conforms with Jayaraman and Singh (2007) and Ayibor (2012), who asserted that there can be no growth achievement without the involvement of labor as a factor input.
- Political stability, trade openness and Gross Capital Formation as a proxy for capital stock were all indicated to be statistically significant in determining economic growth in sub-Saharan Africa.
- The diagnostic tests for the model revealed that, the model passes the tests of serial correlation or autocorrelation of the highest order,

multicollinearity, stationarity, endogeneity and heteroscedasticity taking cure off by the system GMM.

## Conclusions

Based on the discussions and summary above, the following conclusions were reached in accordance with the study's specific objectives.

- ✓ The study confirmed that Urbanisation positively affects economic growth in the SSA countries in the study. The relationship between urbanisation and economic growth is non-linear (inverted U-shape curve). Impacting reversal threshold which is estimated in this study is 33%.
- ✓ However, in assessing the moderation role of the climate variables on urbanisation to affect economic growth, the study concluded that, temperature and precipitation is very relevant in explaining the effect of urbanisation on economic growth in the region. Thus, climate change index also played an insignificant role in moderating the effect of urbanisation on growth.
- ✓ It can be concluded from the analysis that temperature and precipitation are intrinsically non-linear. That is their relationship with economic growth is an inverted U-shape curve. This implies that below a certain threshold level of annual mean temperature, increase in temperature boost economic growth. After this threshold, increase in temperature will tend to detrimental to economic growth.
- ✓ The study also concluded from the discussions that the effect of precipitation on economic growth is an inverted U-shape, that is non-linear. Below a certain threshold level of annual mean rainfall, increases

in rainfall boosts growth performance, all things being equal. After this threshold, increases in mean annual rainfall tend to have damaging effects on growth of SSA countries.

- ✓ Inflation, trade openness, government effectiveness and climate index force exerted a negative and significant effect on economic growth in the region. Therefore, labour force, gross capital formation, political stability, and foreign direct investment, inflation and were also revealed to be significant derivers of economic growth in the SSA.

**Policy Recommendations**

Based on the findings, the following policy recommendations were made:

Urbanisation has the potential to improved economic growth: Governments in SSA countries should prioritize urban development and invest in infrastructure and services to support urbanisation. This can help boost economic growth by creating employment opportunities, attracting investments, and improving productivity.

Again, monitor urbanisation rates and invest in urban planning. As urbanisation positively impacts economic growth up to a certain point, careful monitoring and strategic planning for urban development can ensure sustained positive effects. This might involve infrastructure development, housing policies, and ensuring the availability of essential services in urban areas.

Climate Change Adaptation: Given the significant role of climate variables in moderating the effect of urbanisation on economic growth, policymakers should integrate climate change adaptation strategies into their urban planning and development policies. This can include measures such as implementing green infrastructure, promoting sustainable transportation, and improving disaster preparedness.

Temperature and Rainfall Management: Governments should focus on managing temperature and rainfall levels to optimize economic growth. This can involve implementing policies to mitigate the negative effects of high temperatures, such as investing in irrigation systems and promoting energy-efficient practices. Additionally, measures should be taken to prevent the negative impacts of excessive rainfall, such as improving drainage systems and implementing sustainable water management practices.

Climate Variables (Temperature and Precipitation): Climate change adaptation strategies: Given the non-linear relationship between temperature, precipitation, and economic growth, countries should develop and implement climate change adaptation strategies. This could include infrastructure resilience projects, water management systems, and sustainable agricultural practices to mitigate the adverse effects beyond certain thresholds.

Labour Force: Invest in education and skill development: A skilled and educated workforce contributes significantly to economic growth. Policies focusing on education and skill development can enhance the quality of the labor force, making it more productive and adaptable to evolving industries.

Gross Capital Formation: Encourage savings and investment: Policies that promote savings and investment can boost gross capital formation. This might involve incentives for businesses to invest, tax policies that encourage savings, and the development of financial instruments that facilitate capital formation.

Political Stability: Strengthen institutions and governance: Political stability is a key factor in attracting investments and fostering economic growth. Countries should focus on building strong institutions, ensuring the rule of law, and promoting good governance to enhance political stability.

Foreign Direct Investment (FDI): Create a favorable business environment: Implementing policies that create a favorable business environment, including reducing bureaucratic hurdles, offering incentives, and ensuring legal protections, can attract foreign direct investment. This, in turn, can contribute significantly to economic growth.

Inflation: Implement monetary policies: Central banks can use monetary policies to control inflation. A stable and moderate inflation rate is essential for economic growth. Implementing measures such as interest rate adjustments and open market operations can help manage inflation.

Trade Openness: Foster international trade agreements: While trade openness is a significant driver, ensuring fair trade practices and participating in international trade agreements can maximize the benefits. Countries should focus on negotiating favorable terms and removing barriers to trade.

Government Effectiveness: Enhance governance and efficiency: Governments should focus on improving efficiency, reducing corruption, and enhancing public service delivery. Streamlining bureaucratic processes and ensuring transparency can positively impact economic growth.

Climate Index: Integrate climate considerations into policies: Recognizing the impact of climate on economic growth, policies should integrate climate considerations. This might involve creating incentives for environmentally friendly practices, developing renewable energy sources, and participating in global climate initiatives.

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**Direction for Further Research**

The literature review points to the fact that a lot remains to be done on a theoretical ground and on an empirical perspective, in understanding the relationships between urbanisation, economic growth, and climate change in Sub-Saharan Africa. More specifically, based on the observed lack of consensus, it appears interesting to give more research scope to the relationship between climate change, urbanisation, and economic growth in Sub-Saharan Africa. Future research could explore: (i) multivariate analyses of economic growth, urbanisation, and climate change; (ii) measurement challenges with urbanisation and climate change; and (iii) modeling approaches.

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# APPENDICES

**A: List of countries**

Angola Benin Botswana Burundi Cameroon Central Africa Republic Congo

Congo Republic Cote d'Ivoire Eswatini Ethiopia Gambia Ghana Guinea

Guinea-Bissau Kenya Madagascar Mali Mauritania Mauritius Namibia Niger

Nigeria Rwanda Senegal Seychelles Sierra Leone South Africa Tanzania Togo Uganda Zimbabwe

**B: Threshold estimations**

Temperature square equation = 1.7350 temp -0.028 temp$^2$

$$Threshold = \left|\frac{\beta_2}{2\beta_3}\right|$$

$$Threshold = \left|\frac{1.7350}{2(0.028)}\right|$$

$$Threshold = 31\%$$

precipitation square equation = 0.095prep -0.001 prep$^2$

$$Threshold = \left|\frac{\beta_2}{2\beta_3}\right|$$

$$Threshold = \left|\frac{0,0950}{2(0.001)}\right|$$

$$Threshold = 48\%$$

Urbanisation square equation = 14.683 Urbangrp -0.221 $Urbangrp^2$

$$hreshold = \left|\frac{\beta_2}{2\beta_3}\right|$$

$$Threshold = \left|\frac{14.683}{2(0.221)}\right|$$

$$Threshold = 33\%$$

Climatindex square equation = -1.690 Climatindex + 0.0300 Climatindex$^2$

$$hreshold = \left|\frac{\beta_2}{2\beta_3}\right|$$

$$Threshold = \left|\frac{1.690}{2(0.030)}\right|$$

$$Threshold = 28$$

**C: Interaction estimations**

URBANISATION*PREP

$$GRW_{it} = -1.227URBANGRP_{it} - 0.035URBANGRP * PREP_{it}$$

$$\frac{\partial GRW_{it}}{\partial URBANGRP_{it}} = -1.227 - 0.035PREP_{it}$$

Given the average PREP of 3.044 then $\frac{\partial GRW_{it}}{\partial URBANGRP_{it}} = \mathbf{-1.335}$

URBANISATION*TEM

$$\_GRW_{it} = -1.3120URBANGRP_{it} - 0.002URBANGRP * TEM_{it}$$

$$\frac{\partial GRW_{it}}{\partial URBANGRP_{it}} = -1.312 - 0.002TEM_{it}$$

Given the average TEM of 36.756 then, $\frac{\partial GRW_{it}}{\partial URBANGRP_{it}} = \mathbf{-1.38}$