THE IMPACT OF WEATHER VARIABILITY ON ECONOMIC GROWTH IN KENYA

BY

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DECLARATION

This research paper is my original work and has not been presented for a degree award in any other university.

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This research paper has been submitted with my approval as University supervisor.

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Dr. George Muniu Ruigu Date

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This study is dedicated to my mother, the late Alice Nyangena and to my grandfather, the late Samson Mwamba to whom I owe all that I am and that I am yet to be.

ABSTRACT

The effect of weather and climate variability on economic performance is ordinarily estimated using simulation models that predict the magnitude of long-term implications under normal and adverse scenarios. These models do not provide information that can enable policy within the short-run. Understanding how weather behaviour can influence economic growth over short periods is particularly important in predicting future economic performance of an economy. This paper set to explore the influence of weather change on economic performance in Kenya. The time series data from the World Development Indicator and the World Bank climate change portal for the last 50 years (1964-2013) was used. Upon carrying out various time series diagnostics tests, analysis was done based on the Vector Error Correction Model. The results showed that total rainfall had a negative relationship with gross domestic product while change in temperature indicated a positive relationship; however the magnitude of these relationships differed by magnitude. Change in human capital formation resulted to a negative contribution on gross domestic product per capita growth because increase in knowledge leads to massive production that increases carbon dioxide gas concentration in the atmosphere, which has economic implications. Finally, change in the total population parameter indicated that the magnitude of output decreases with increase in population. The study recommends that appropriate measures are put in place to help the vulnerable poor to adapt and to mitigate in the face of weather variability.

ABBREVIATIONS AND ACRONYMS

ASAL	Arid and Semi-Arid Land(s)
CERES	Crop Environment Resource Synthesis (model)
CO_2	Carbon Dioxide (gas)
EMG	Environment Management Group
ENSO	El Niño Southern Oscillation
EU	European Union
GHG	Green House Gas
IAM	Integrated Assessment Model
IPCC	Intergovernmental Panel on Climate Change
KEMRI	Kenya Medical Research Institute
KMD	Kenyan Meteorological Department
KPDNA	Kenya Post-Disaster Needs Assessment
NASCOP	National AIDS and STI Control Programme
NDVI	Normalized Difference Vegetation Index
SSCM	Semi-parametric Smooth Coefficient Model
SEI	Stockholm Environment Institute
SSA	Sub-Saharan Africa
TFP	Total Factor Productivity
UNICEF	United Nations Children's Fund
WB	World Bank
WDI	World Development Indicator(s)
WHO	World Health Organisation

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CHAPTER ONE

INTRODUCTION

1.0 Introduction

In this chapter, relevant studies that form the basis to understanding the weather-economic growth nexus are presented. An overview of weather extremes, objectives which the study focuses on, its scope and breadth as well as the organization of subsequent chapters are presented.

1.1 Background of the Study

Adverse weather events are a challenge with multiple effects. Predictable and favourable weather is particularly important for sustainable development. But plummeting levels of precipitation over an abnormally long period is spanning constraining socioeconomic impacts to societies (Rouault & Richard, 2003). Extreme weather has become more severe and frequent, seriously affecting sectors which are sensitive to weather changes such agriculture, livestock and fisheries, tourism, energy and forestry. Worldwide, changes are being felt. Of the world's vast terrestrial surface, about 40 percent is dry land and a home to over 2.5 billion people. Between 10 to 20 percent of this cosmic portion is subject to some form of vulnerability to environmental changes yet investment and meaningful development interventions such as irrigation have not been practiced in this area. There has been a subjective understanding of drought and flood occurrences in developing countries yet the Sub-Saharan African (SSA) countries have continued to register significant levels of poverty (Mortimore, 2009).

Parts of the world that hitherto received high average rainfalls are now experiencing major shifts in precipitation and facing the challenge of acute water scarcity (Rathore, 2014). These shifts are mainly triggered by three major factors namely: the West African Monsoon, El Niño Southern Oscillation (ENSO) and the Inter-Tropical Convergence Zone (ITCZ). However, little is known about how climate variations influence the interaction of these three forces. Various climate models estimate increases in median temperatures between 3 to 4^0C in the African continent by the year 2100, which is nearly 1.5 times the global mean response temperature (Collier *et al.,* 2008; Okoba *et al*., 2011).

Weather variations have drastically changed the conventional perception of drought as a weather event that affects arid and semi-arid areas (ASALs). It is evidenced that occurrence of a drought event can significantly impede the gross domestic product (GDP) growth rate of a country by 2.7 percent per annum with a unit increase in percentage of drought affected area whereas a unit increase in percentage of rainfall in a given area has potential to shrink a country's GDP by about two percent per annum (European Commission, 2014). Directing synergies to avert land degradation and promote sustainable development in the affected areas in the face of harsh weather has major implications for not only climate change and food security but also on human settlement and overall economic growth (EMG, 2011).

In order to address above issues of environmental degradation, improving human wellbeing and consequently boosting the overall pace of economic growth, it is important to appreciate the empirical fact that swings in weather are responsible for increased migration of animals and plants from their territories, which is not without serious economic ramifications (Ferrara, 2015). Average temperatures have continued to swell laying ground for a possibility of drought-affected areas increasing in the future. The majority of the countries in the developing world already experience considerable development constraints because of their poor coping and adapting strategies to a changing environment. As a consequence, these shifts in environment are exacerbating the existing development problems that these countries face (Okoba *et al*., 2011).

A spatial global analysis of data on land use change revealed that Asia, and not the African Sahel, has experienced the most severe dryland degradation. Escalations in annual average temperatures and seasonal rainfall variability are already affecting drought sensitive sectors and have dwindled possible gains. Although there is a likelihood of gainful trends in productivity in some African countries despite the drought and precipitation levels of 300 to 500 mm that are adequate for wheat yields of up to four tonnes per hectare, there is also growing evidence of the continent 're-greening' since 1980 meaning clear shifts of drylands (EMG, 2011; Lepers *et al*., 2005).

The horn of Africa, like in most parts of the continent; agricultural activities are heavily dependent on rainfall. Environmental variations pose new challenges to agriculture affecting farmers and yields quite disproportionately with the poor who have scanty resources to adapt to these variations bearing the economic brunt. Already, crop yields are reducing yet ASALs are anticipated to widen by as much as eight percent by 2080, which is heavily attributable to diminishing water resources (IPCC, 2001). It is also anticipated that the situation in agricultural productivity will worsen by the year 2020 with yields in grasslands shrinking by between 50 to 90 percent in ASALs alongside the extension of soil salinity and widespread water scarcity across the continent (EMG, 2011).

Kenya is anticipated to experience nation-wide losses in the production of major staples because of anticipated escalations in evapotranspiration as a result of increased temperatures. The agriculture sector, which is a major source of income and main source of employment for the majority of rural population, will be affected the most. Appropriate adaptation measures are important in promoting resilience of the sector, enhance food security for the people and protect the welfare of the majority poor. Drought response strategies, which include crop and animal response management systems, land use management, soil and water conservation and management are some of the viable adaptation measures that have great impact in reducing the extent of vulnerability to harsh weather and changing climate (IPCC, 2001; Thornton, 2006).

Data on drought events that has been recorded in Kenya since 1970 to 2011 suggest that drought poses considerable risks than floods when weighted by its influence on GDP. Analysis on this data showed significant decreases in agricultural productivity, falling rural incomes and export earnings from agriculture, declines in consumption and on levels of investment, employment and expanding multiplier effects on the monetized economy (Seitz & Nyangena, 2009).

1.1.2 Overview of El Niño and La Niña Impacts on Economy

Ordinarily, the effects of heavy rainfall are localized. But in 1997/1998, Kenya experienced heavy levels of precipitation that were characterised by sweeping landslides and devastating floods over a 10 months period (Ngecŭ & Mathu, 1999). Such variations in levels of precipitation in an area suggest strong relationship to ENSO weather event during which average levels of precipitation increase as a result of variations in temperature in the Indian Ocean (Nicholson, 1996). During the 1997/1998 El Niño event, Kenya endured losses of up to US dollars 1 billion. Mudslides and avalanches precipitated by the weather event were colossal and deposits brought power generation at various dams to a halt (Ngecŭ & Mathu, 1999). Nonetheless, on a yearly basis, the country loses approximately 3.8 percent of GDP to massive soil erosion processes (Cohen et al., 2006). Over and above, the country encounters an overall loss to floods alone that is approximated at Ksh 38 billion, on yearly basis (Di Gregorio *et al.* 2015).

Since 1980, temperatures in the East African region have increased by 0.5 ^{0} C and rains provided ideal breeding zones for mosquitoes whose population has strikingly risen (Yanda & Mubaya, 2011). Kenya has particularly endured major shifts between El Niño and La Niña every five and seven years respectively, since 1970, with La Niña being more recurrent and accounting for nearly 10 percent reduction of GDP, an equivalent amount of Ksh 50 billion (Di Gregorio, Locatelli & Pramova, 2015). This erratic weather is largely attributed to the increasing cases of not only malaria and dengue fever but also cholera and other water borne diseases as the vulnerable are exposed to poor hygiene and sanitation. Malaria alone shrinks income by 66 percent whereas combating the disease by 10 percent alone leads to gains in growth of up to 0.3 percent (Collier *et al.,* 2008; Yanda & Mubaya, 2011).

During the 2005/2006 La Nina event that affected ASALs in the north western part of the country, spurred conflicts for resources among affected communities with pastoralists counting losses of nearly 95 percent of livestock leaving them hungry and poor. During a three year period (between 2008 and 2011), the country experienced high temperatures characterised with drought exacerbated immense damages and losses that amounted to over US$ 10 billion. Physical infrastructure and assets worth more than US dollars 12 billion were demolished. Livestock and crop agriculture incurred losses beyond US dollars 8,200 million that cost the government over US dollars 1,115 million to recover and rebuild the two sectors (KPDNA, 2012).

Over and above, during La Niña, people are compelled to share water resources with animals. This puts the lives of people and animals in the danger of contracting diseases from each other. More importantly, the sick, women and children, the elderly, the physically challenged and people living in riparian areas where both infrastructural and communication facilities are poorly developed suffer the most from this risk (Di Gregorio *et al.,* 2015; Yanda & Muyaba, 2011).

1.2 Statement of the Problem

Drought is an endemic natural catastrophe that threatens GDP growth in Kenya. The consequences of a continuation of this catastrophe are adverse and dynamic both in nature and scale from one region of the country to another. ASALs account for about 80 per cent of Kenya's land area. A greater portion of this segment lies in the northern parts of the country where more than 10 per cent of the country's population of 45 million people reside. In these vast ASALs the population derive their livelihood mainly from pastoralism. A variety of rangeland users also depend on this area for their existence (Tilstone *et al.,* 2013). While it is conventional wisdom that drought emanates from inadequacy or absence of rainfall, economists want to know how this shortage and variation impacts on economic operations of a society without irrigation (Rouault & Richard, 2003).

Prolonged periods of bad weather make life unbearable for the general population by reducing its economic prospects, which are ultimately not without serious ramifications on GDP growth. Drought is particularly widespread and more recurrent than floods, which are localized and less frequent. As a result, levels of agricultural productivity, consumption, investment and saving habits of the population are affected. For instance, Kenya's pastoralism is estimated at Ksh. 80 billion but is at risk to the fluctuating weather. This risk will continue to pose a challenge even into the future. This is in spite of a close examination of patterns of precipitation using NDVI data for Kenya that suggests that there is a stability of drought frequency and that erratic rainfall has not changed over time (Thornton, 2006). But empirical evidence shows that weather variations are spurring significant swings in average temperatures (Tilstone *et al*., 2013). With the country's poor coping mechanisms to changing weather and susceptibility of its poor population, the consequences of this phenomenon can have negative impact on Kenya's economic growth yet only a narrow investigation exists in this regard.

SEI[1] (2009) sought to investigate this problem that has devastating macro-economic implications even into the future but their investigation was not done empirically. This study

[1] The study found that drought, which affects the whole country, is responsible for a 2 percent GDP loss alongside long-term growth reduction. SEI (2009) observed that Kenya is not ready to address the weather risks of drought, of fluvial and pluvial floods, which affects about 1 million people across the country, annually.

seeks to explore the link between weather variability and economic growth by assessing its impact on gross GDP per capita.

1.2 Research Questions

This study was guided by the following research questions.

1. What is the impact of weather changes on economic growth in Kenya?
2. What is the policy implication on economic growth in Kenya?

1.3 Objectives of the Study

The general objective of the study was to explore the link between weather and economic growth in Kenya. The specific objectives of the study include:

1. To analyse the impact of weather changes on economic growth in Kenya
2. To formulate the weather change-economic growth policies in Kenya

1.4 Significance of the Study

The study is of great importance in a number of ways. First, globally, few studies that have focused on the effect of both temperature and rainfall on economic growth, which this study seeks to investigate. Previous studies have either considered rainfall or temperature and have therefore failed to provide the full-range-impact of variations in weather.

Second, the population of Kenya is gradually exploding and was estimated to be 45 million in 2014, having increased by 6.3 million from 21.4 million to 28.7 million between 1989 and 1999 (KNBS, NASCOP & KEMRI, 2010). This population has almost doubled that of 1989 but productive resources per capita are on the decline. Estimated to be increasing by 2.9 percent annually, Kenya's population is projected to nearly double and reach 85 million by the middle of this century (WHO & UNICEF, 2014). An understanding of these dynamics will help policy makers to plan accordingly so that the lives of the future population are not jeopardised.

Floods events have intensified and there are myriad socioeconomic effects associated with them. Drastic weather changes are shifting planting seasons. Productivity in livestock and crop farming is falling and uninformed decision making and enabling policies to support farmers and pastoralists with regard to weather extremes is rendering the poor huge economic losses-a problem this study seeks to contribute to providing a solution. This is motivated by an understanding that policies that can cushion crop and animal farmers in view of the changing environment have to be dynamic and contextual especially under the new constitution dispensation of 2010 when the county governments have the mandate to take charge of agriculture, collect revenue, prepare and execute their own budgets. The study will provide new insights to existing laws and policies and help the (the county and the national) government draw appropriate amendments that will account for this understanding in the revenue sharing formula and in formulating innovative ways to cushion the poor against the harsh effects that come with unpredictable weather events.

Most importantly, this study is not only a contribution to literature but to the model as well as it introduces an additional variable to the existing model. Nonetheless, we learn from past events or judge the present and harness policies to tackle the future by understanding similar past events. That way, the country can sustain its GDP growth despite unpredictable rains, whirling winds and rising temperatures (Di Gregorio, *et al.,* 2015; Rouault & Richard, 2003).

1.5 Scope of the Study

This study covered the entire country and focused on weather variability and challenges that these variations portend over the period, 1964-2013.

1.6 Organization of the Study

Subsequent chapters of this study are organized as follows; chapter two will focus on literature review where theories as well as contextual empirical studies on which the argument under study is anchored will be discussed and an overview provided in the latter part of the chapter. Chapter three will present the methodology, first, the theoretical model then the empirical model that will define the model applied in this study. Chapter four will provide a detailed analysis of statistical output whereas chapter five will encompass policy recommendations and conclusion.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

In this chapter, two main components, theoretical and empirical evidences, are presented. Under the theoretical component, three theories are discussed namely: the chaos theory, the decision theory and the neo-Malthusian theory. Under the empirical component, global, developed countries studies, regional as well as national perspective studies are presented with an aim to understand the methods and variables used in the studies, which will inform the choice of methodology in the next chapter.

2.1 Theoretical Literature

2.1.1 Chaos Theory

Chaos theory (by Lorenz, 1963) seeks to explain confusion, disorder and turbulence, unpredictability and uncertainty of diverse phenomena. This theory has two essential assumptions that describe what a chaotic system is: sensitivity to an initial condition and dynamic non-linear patterns that are not fundamentally random. Parameters are also pre-empted to be independent such that it requires an understanding of the initial point for predictability to hold. A (chaotic) system is purely deterministic and assumes absolute dynamism to the extent of exhibiting unpredictability in standard statistical tests, rendering it to be chaotic (Lorenz, 1963). Small measurement errors within the short-run can prompt independent or distinct computational outcomes in the long-run. Simple linear set ups, unlike the dynamic and non-linear set ups are fundamentally both orderly and predictable. Over the short run (for weather behaviour) and not in the long run (for climate behaviour) deterministic chaos is hugely orderly and predictable, however new findings suggest that it is only easier to forecast climate than weather because the former is governed by an imbalance of the world's energy forces (Stephens *et al.*, 2012).

But chaotic systems such as weather or economic growth are nearly impossible to predict, failure to which damages (such as droughts due to pummelling temperatures, floods, storms and mudslides due to intense rainfall) do not fail to take place. Concisely, predictability outcomes under dynamic set ups for particles (reduced issues) are not different, insinuating inconsistency in these models. Hence, there is an inverse relationship between predictability and dynamisms of nature of a given system. Conversely, an understanding about reduced issues (in scope) about a given theme is essentially paramount to unravelling even larger issues on a wider scope because reduced issues are not hinged on their own independence.

In a set up where there are short term turbulences or fluctuation in measurement, accurate predictions are impaired. Over and above, minute changes in predictor (independent) variables trigger similar changes in the predicted (dependant) variable. This implies that a simple set of dynamic equations has minute oscillations being responsible for acute inconsistencies. For instance, the theory is elaborate that business cycles are not deterministic in a manner that negative or positive economic outcomes cannot be traced directly to either expansions or recessions per sè. Perhaps, the greatest strides of this theory are utilizing these models for predicting phenomena where only little is known about them. This achievement superimposes cases where only diagnostic tests are applied.

Economic growth embraces randomness and predictability. To limit the extent of chaos in measurement, close estimates are used to encapsulate analytical outputs based on an assumption that there is a linear behaviour in variables under estimation. Where predictability is dynamic, some variables are intricately responsible for this state, of which they should not be sidelined but involved. This gives way for creation of more complex predictability models. Inspection of chaotic systems (over time) does not imply that those systems have or had chaotic conceptions. This is because chaotic systems can have uncomplicated causes as their conceptions. Erratic shocks or white noise are responsible for indeterminate fluctuations, in turn, leading to quite unmanageable models. To that end, what may be perceived to be dynamic, complex or even random essentially describes a chaotic system.

Natural disaster risks such as floods, landslides, storms, drought etc. are driven by indeterminate order. Economists are interested in unravelling this disorder. A set of simple and short mathematical expressions lead to long and dynamic series. Because of this, it is very complicated distinguishing between a set of randomness and chaos by applying general standard stochastic tests. Especially when multiplex data is used in modelling observed data, it becomes almost unlikely that simple correlations can be generated. It is also difficult connecting stochastic data with indeterminate equations.

2.1.1.1 Chaos Theory, Weather and the Butterfly Effect

The butterfly effect is an illustration that Lorenz (2000) used to explain critical property of the chaos theory, which is sensitivity to initial conditions, otherwise known as the stochastic chaos. This illustration serves to explain the reality that 'micro' issues have potential to spur 'macro' outcomes. A multifaceted model structure based on computer simulations was developed to unravel this relationship. Upon monitoring the behaviour of the model, conclusions were reached that even inevitably small errors had important influence on outcomes and that by truncating decimals in outcomes the magnitude of error was actually magnified. A flap of the butterfly's wings is like the seemingly small errors experienced in a present state that are bound to happen in subsequent states, which is the essence of the butterfly effect. Predictability is closely tied with what people can express using equations, assess or observe while to determine is tied to behaviour of a system under observation. It is concluded in this illustration that making future weather forecasting is hard. It is only practicable to forecast the weather behaviour in the future when a trend is observed from some initial weather condition.

2.1.2 The Decision Theory

Arrow (1960) formulated the decision theory as it has ever been known since. The theory sought to explore possibility of overcoming unpopular decision outcomes (than the majority arguments) such that cyclic outcomes do not prevail. But in making a decision, both the reliability and unreliability of postulated outcomes are taken into consideration in analysing a decision. From this development, it is the duty of a risk analyst to assemble all feasible information to settle on a risk. The value of the risk estimate should account for a measure of precision and imprecision. Conventionally, this value fluctuates between zero and one. So arriving at a decision subject to uncertainties is hectic.

Weather-induced disaster risks and uncertainties are disadvantageous to economic performance of an economy. This is because of the unpredictability of weather events. Uncertainty and decision making in economics (Heal & Millner, 2014), allow space for the unsettlement of model, initial condition and emission (of greenhouse gases) uncertainties add to atmospheric mean temperature. Uncertainty under the initial condition is particularly important for weather forecasting. Over long periods, it is the emission uncertainty that plays a major role. The relationship between greenhouse gases such as carbon dioxide (CO_2) and temperature is apparent in climate research. Uncertainties increase when dealing with meteorological variables like rainfall whose shocks are localized.

Empirical uncertainties entail absence or inadequacy of knowhow with regard to inventions, innovations that can possibly shed more light in understanding interactions of weather events and climate variability. To sum socioeconomic uncertainties, there is also an element of normative unsettlements about the main parameters of well-being. A failure to critically analyse these uncertainties versus the scientific uncertainties, make it moribund in policy making. But even if economists and researchers reached a consensus on ways to estimate impacts of weather variations on human activities, robust predictability of weather changes will remain foiled and hectic because it requires knowing what the future GHG emissions will be. Even if the levels of emissions were to be correctly projected or quantified, a range of aspects are obscured in understanding the future. Over and above, the economic cost of weather disasters and climate catastrophes in but another uncertainty.

Uncertainties surrounding studies that have dwelt on effects of weather and climate change on economic growth (Dell, Jones & Olken, 2012; Colacito, Hoffmann & Phan, 2014; Bloesch & Gourio, 2015) have to do with estimating the impact of these shocks. Results show that impacts will be severe and will impair the socioeconomic welfare of the people and shrink economic growth rates. Levels of CO_2 content in the atmosphere affect temperature. Yet it is technology that actually influences the magnitude CO_2 emissions. An improvement in technology also affects economic performance and is a main determinant for not only energy demand and consumption in the future but wealth creation.

2.1.3 The Neo-Malthusian Theory

The neo-Malthusian theory suggests that a fall in natural endowments is as a consequence of a range of drivers chiefly environmental scarcity that spur socioeconomic as well as political tensions. This theory connects consequences of prolonged droughts, massive deforestations, floods, water scarcity and other climate related challenges to increments in these tensions. The theory is strongly advocated for on an understanding that overexploitation of limited natural resources as a result of increases in population, affects economic outcomes. Malthus had earlier argued that exploding population will not match food production.

The concept of environmental scarcity has three main dimensions: the structural, supply and demand dimensions of scarcity. Structural scarcity entails when only a small portion of the population is made custodian of the majority of the available resources while the rest of the population struggles to make ends meet using the few resources at their disposal. When resources are utilized faster than they can regenerate it defines supply scarcity. Demand scarcity is generated by population dynamics. These three tenets are responsible for constant migrations and are gradually shrinking agricultural and economic performance that are in turn responsible for increased tensions.

This theory also argues that environmental catastrophes are resulting from the ever increasing population of the poor who over-utilize environmental goods. Containing population explosion of the poor in a niche to its carrying capacity is thus instrumental in curtailing the extent of potential environmental damages. The notion of carrying capacity is closely tied on a number of assumptions. First, it assumes a closed economy without imports or exports such that all that is produced is locally consumed. Second, it is assumed that the population consumes equal shares of what the local economy produces. Third, the local economy is homogeneous and serves production of consumption good only. Lastly, operations of the local economy are dynamic over time.

2.2 Empirical Literature

2.2.1 Global Perspective

Dell *et al.,* (2012) in exploring evidence from the last century of variations in temperature shocks on economic outcomes for global economies, use the Integrated Assessment Model (IAM) approach, based on global time series rainfall and air temperature for the period spanning nearly a century between 1900 to 2006. IAMs are widely used in the confines of climate change to model relationships between meteorological variables and economy. They argue that increases in temperature considerably downsize economic growth by lowering the levels of output and impede growth rates among struggling economies. Findings show that increased temperature has widespread impacts. Levels of agricultural yields and industrial outputs decline. The political atmosphere becomes more chaotic among developing economies. As a result, these findings suggest, an economy's overall pace of development is significantly reduced. This reduction is also augmented by the sheer fact that across the majority of struggling economies, investments for productive growth are weather-sensitive.

Jenkins (2011) modelled the socioeconomic impacts of drought, taking into account of long-term estimates of climate change. Although the study applauds the utilization of the climate models in making future climate change estimates, the study posits that there are narrow methodologies to do this assessment.

2.2.2 Developed Countries Perspective

Colacito *et al.,* (2014) sought to investigate the relationship between temperatures and growth using a panel analysis in the United States (US). Although they appreciate the difficulty that is involved in establishing this nexus, their findings are consistent with those of Dell *et al.* (2012). From the foregoing, Colacito *et al.* (2014) in their measurements, establish that in aggregate, increases in temperature are responsible for significant declines in the growth rate of the US GDP by nearly 33 percent, which translates to enormous welfare losses.

Bloesch & Gourio (2015) analysed the weather effects of winter on the economy of the US. They used regression analysis based on snowfall and temperature data assembled between 1950 and 2014 from 1,200 weather stations across the US. They give insightful notes to quality of the data used. They claim that data quality can be affected by change of instruments, time of observation or environment due to human activities and further argue that although these seemingly small changes may not have significant effects over the short run predictability of weather, they are very important when making medium term to long-term weather predictions. Their findings indicate that although weather has negative effects on economy, these effects are short-lived. However, weather-sensitive sectors are affected the most. It is also important to note that although researchers have used algorithms to account for possible errors, their analysis did not accommodate these adjustments.

Van-Passel, Massetti & Mendelson (2012), used a Ricardian approach in examining the climate change effect on European agriculture. The model was designed to suite a continental scale under two scenarios: moderate and severe scenarios. Massive survey was conducted to collect data across the continent that covered 37, 612 private farms. Climate, geographical as well as socioeconomic variables were considered. Results suggested that climate is responsible for the declining farmland values in the EU. Results further suggested that rise (fall) in precipitation will lead to a mean rise (fall) in returns by 3 percent with a unit (centilitre) rise in rainfall. Simulated impacts under each scenario suggested a possibility of agricultural loss of 8 and 44 percent under the moderate and severe scenario, respectively.

Hor, Watson, & Majithia, (2005) modelled the influence of monthly meteorological weather variables vis-à-vis electricity demand on monthly basis in the United Kingdom (UK). They generated a multiple regression model to predict demand. The model also included population growth and GDP, and results revealed that actually, weather events significantly influence operation and consumption of electricity in the country. Zeb (2013) investigated, among the Nordic countries, the extent to which variations in temperature influence a country's level of output using a 40 years period dataset ranging between 1960 and 2000. Results showed that temperature variations have a dynamic impact that is also indirect. The method[2] used also showed that the point-wise measurement of capital accumulation falls with a rise in temperature.

Bigano *et al.* (2005) in examining the extent of climate change and adverse weather events on tourism have used panel regression estimates for selected sectors (under the country's multi-sector project dubbed as WISE) of the Italian economy. They used national aggregated data under different periods between 1983-1989 and 1990-1995. They observed that there are minimal fluctuations in weather variables throughout the region of their study suggesting homogeneity of weather. Although the weather-tourism nexus is both multidimensional and complex, their results show a general positive influence of temperature on tourism except in winter. Domestic holdings rise by 0.8 to 4.7 percent with respect to a unit increase in summer temperature. Most importantly, allude that people's perception of weather changes in the future has an important effect on the performance of the tourism sector in the sense that anticipations for adverse weather lead to low tourists turnout, and vice versa.

2.2.3 Regional Perspective

Closer to home and in SSA, several studies have explored the impact of weather and climate variability on the performance of economic activities. For instance, Elshennawy *et al.* (2016) critically examined the relationship between climate change and economic growth in Egypt using an inter-temporal general equilibrium simulation analysis to understand future prospects of agricultural and labour performance and expected losses as a result of the much anticipated rise in sea-level on the country's aggregate income, consumption and investment. The results of the simulation analysis are strikingly important. They reveal that absence of viable adaptation options will reduce the country's level of GDP by 6.5 percent in 2050 vis-à-

[2] The study utilized the SSCM regression approach that merges both the parametric and the nonparametric models.

vis a 2.6 percent decline when meaningful adaption policies are in place. In order to counteract this climate induced impulse, people that are at risk the most to the changing climate should be cushioned and helped to adapt. Investments in irrigation and diversification options should be highly propagated for.

Bello & Maman (2015) examined the influence of temperature and rainfall variations on agricultural performance in areas of Maradi and Dosso in Niger under two scenarios: in the presence and in the absence of adaptation, using a Ricardian approach. Data from 200 farms were incorporated in this examination. The findings established that a unit increase in annual temperature resulted in a decline in crop returns by US dollars 2.6 and US dollars 1164 in the model that considered adaptation and one that did not, respectively. The study concluded that despite the escalating weather, losses can be averted by a significant margin of 8.95-12.71 percent, if farmers chose to adapt. Kurukulasuriya *et al.*, (2008) used a similar approach to determine the influence of climate variability on African cropland. They assembled cross-sectional data from over 9,500 farmers across 11 African countries. Their findings are quite consistent with those of Bello & Maman (2015) that variability influences net returns of agriculture across the continent.

2.2.4 National Perspectives

Mboya, (2013) analysed the influence of both weather and climate variability on fishing in Homa Bay county, Kenya. The study also evaluated fishers' capacity to adapt to the two variables under weather and climate variability. The results show that fluctuations in temperature, wind and storms, drought and increases in temperature have significant negative effects on fishing activities. He recommended livelihood diversification among fisher folks. Kagunyu (2014), on examining the livelihood of the Borana pastoralists in Isiolo county, Kenya, notes that although some coping mechanisms have been harnessed in the region to cushion the people against harsh weather (floods and drought), these mechanisms are only short-lived due to frequent flood and drought occurrences.

Ngecŭ & Mathu (1999), in their much detailed study on the socioeconomic repercussions of the El Niño-prompted landslides in Kenya, observe that the country experienced adverse effects of El Niño that was characterised by heavy levels of precipitation accompanied by extensive landslides between May 1997 and February 1998. The entire period was extremely wet. Geological factors such as soil type and topography accentuated soils and rock saturation leading to immeasurable but huge losses. Infrastructural facilities such as roads and bridges, telephone and power lines were destroyed and Kenya underwent an economic shock of over one billion US dollars. Concisely, Nyang'au *et al.* (2014) on measuring rice productivity in changing weather conditions in Kenya have used rice growth and development data over the 2011 planting season on CERES rice model that accounts for variations of soil water content on yields. Their results show a dual effect such that rice productivity is not only affected by atmospheric carbon content per se, which has a positive effect, but also by increases in both maximum and minimum temperatures that have a negative influence on total rice yield.

Kabubo-Mariara & Karanja (2007) applied a ricardian approach to analyse the climate change impact on Kenya's crop agriculture. The study used cross-sectional data from 816 households. The findings suggested divergent outcomes on influence of temperature and rainfall with temperature, unlike rainfall that caused positive impact, having negative influence on the production crop agriculture. These findings were consistent with those of Wandaka (2013) who used a similar approach as Kabubo-Mariara and Karanja (2007) to study the impact that climate change portends on maize crop performance in Kenya. The findings revealed that the June-August rise in rainfall and the March-May period rise in temperature spurred negative crop output effects. Conversely, intensified rains during the March-May period suggested positive crop output effects with temperature having a superimposed influence than rainfall on maize crop output levels.

Kabubo-Mariara & Kabara (2014) assessed the state of food crop security in the face of climate change in Kenya. Future climate simulations as well fixed and random regression outcomes were determined using panel data that included main crop yields and daily meteorological data variables collected at the county level. The results suggested that climate change and variability will worsen the food security situation. Gleditsch, (2012), who incorporates Kenya in a study on the climate change-conflict nexus, reflects that there are communities who experience hostilities during wet seasons while tranquillity prevails during drier seasons.

2.3 Overview of Literature

The underlying literature revealed some empirical incongruity among studies that have sought to investigate the role of weather and climate fluctuations and economic growth. Chaos theory overarches this (weather-growth) argument because of its incredible utility in explaining tests for a range of dynamic set ups though certainty of deterministic chaos in such set ups is not strong. Limitation of number of studies in this regard draws the need for further empirical research on people's perceptions of weather to unravel its underlying economic consequences.

Various studies[3] have suggested economic ramifications as a consequent of temperature increases but Bigano *et al.* (2005) and Gleditsch, (2012) have maintained potentiality for economic gains with increases in temperature. The ricardian[4] studies although instrumental in contributing to the empirical research with regard to this subject, and in spite of considering a range of climate variables including temperature, soils and rainfall, geography and (accommodating a range of) socioeconomic factors have only succeeded in providing future adaptation options and solutions in view of the seemingly existential changing climate and weather. This implies scanty of empirical knowledge on how, over the short run, weather-induced problems should be addressed to enable viable adaptation options. Utilisation of cross-sectional datasets, result in selection bias and findings can only be generalized over the defined population. The study borrowed from Zeb (2013) who considered linearizing the Cobb-Douglas production model and introduced the meteorological variable of temperature (as an external shock) to the study as an added determinant of growth in the growth model.

[3] Dell *et al.*, (2011), Kurukulasuriya *et al.*, (2008), Kabubo-Mariara & Karanja, (2006), Nyang'au et al., (2014), Mboya, (2013), Bello & Maman, (2015), Colacito *et al.*, (2014) and Wandaka, (2013).

[4] Kabubo-Mariara & Karanja, (2006); Wandaka, (2013); Bello & Maman (2015).

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter presents the approach used in the study following the theoretical as well as the empirical evidence provided in the preceding chapter. First, the theoretical model, and then the empirical models are presented, upon which the model applied is delineated. Finally, rigorous pre-estimation and post-estimation (statistical) tests then data types and their sources are presented in the last part of the chapter.

3.1 Theoretical Model

Extreme weather has great potential to reduce a country's economic outcomes. Bad weather impairs health of the general population thereby affecting its (the population's) economic performance. A country's total factor productivity (TFP) is also affected. Since weather is assumed to affect productivity, meteorological variables of temperature and rainfall, are directly added in the model as additional variables explaining performance of the economy. Borrowing the empirical work of Zeb (2013), this study adds meteorological variables of weather, temperature and rainfall, in the model[5]. A stepwise approach of the (linearized) model used in this study by first utilizing the Cobb-Douglas production function with presence of TFP, labour and capital is systematically presented as follows:

$$Y = AK^{\beta}L^{(1-\beta)} \qquad \text{(i)}$$

Where Y = real GDP is the real aggregate income, K, denotes the physical capital, L denotes labour while A is the TFP. It follows that the total factor productivity, A, is defined as shown below:

$$\ln A = \lambda X \qquad \text{(ii)}$$

[5] The Solow-Swan model (of 1956), which assumes a Cobb-Douglas production function, the Weil-Mankiw-Romer model (of 1992) and the Koopmans-Cass-Ramsey model (1965) have an ample application in analysing effects that fluctuations in weather (variables) portend to levels of investment, long-run capital stock accumulation, per capita consumption rates, effects on demand and GDP (Zeb, 2013).

Where λ is denotes a vector to be measured and X, set of weather variables that directly influence economic performance. For purposes of simplicity, a deliberate assumption is made about labour, L, that it grows exponentially at a rate n over time, t. It therefore follows that:

$$L = L_0 e^{nt} \quad \text{(iii)}$$

Per unit output is denoted by $y_t = (\frac{Y_t}{L_t})$ while stock of capital is given by $k_t = \left(\frac{K_t}{L_t}\right)$. Dynamic change of capital over time (denoted by '˙') is provided by the equation:

$$\dot{k}_t = [\alpha_t^k y_t/(n + \delta)]^{1/(1-\beta)} \quad \text{(iv)}$$

α_t^k is a share re-invested physical capital in period t. δ denotes the rate of depreciation. The capital stock steady state equation is expressed as:

$$k_t^* = \alpha_t^k y_t - (n + \delta)k_t = \alpha_t^k k_t^{\beta} - (n + \delta)k_t \quad \text{(v)}$$

To generate the reduced form equation of the Solow growth model, equation (v) is substituted into equation (i).

$$\ln y_t = \varphi_0 + \varphi_1 w_t + \frac{\beta}{(1-\beta)} \ln\alpha_t^k - \frac{\beta}{(1-\beta)} \ln(n + \delta) \quad \text{(vi)}$$

Where, φ_0 denotes the intercept and w_t the weather variables.

Weil, Mankiw and Romer (1992) argued for the inclusion of human capital to the Cobb-Douglas production function. Their definition of growth is expressed as shown below:

$$Y = AK^{\beta}H^{\theta}L^{(1-\beta-\theta)} \quad \text{(vii)}$$

Considering time variation, now the equation below accounts for changes in real aggregate income or real GDP over time.

$$Y_t = A_t K_t^{\beta} H_t^{\theta} L_t^{(1-\beta-\theta)} \quad \text{(viii)}$$

Where H_t denotes the human capital stock, which is the novelty that Weil *et al.*, (1992) provide. Consequently, human capital dynamisms are denoted by $h_t = (H_t/L_t)$. in their model, population is also assumed to be changing at a constant rate n with δ denoting the rate of 'wear and tear' for human as well as physical capital. Now the reduced form expression of the Weil-Mankiw-Romer model is given as:

$$\ln y_t = \varphi_0 + \varphi_1 w_t + \frac{\beta}{(1-\beta-\theta)} \ln\alpha_t^k - \frac{\theta}{(1-\beta-\theta)} \ln\alpha_t^h - \frac{\beta+\theta}{(1-\beta-\theta)} \ln(n+\delta) \qquad \text{(ix)}$$

3.2 Empirical Model

Consistent with the description of the theoretical model, the empirical model specifies the model the study will use, with weather variables of temperature and rainfall introduced to the model. The empirical model is expressed as:

$$In\ y_t = \beta_0 + \beta_1 Ink_t + \beta_2 Inhnc_t + \beta_3 Inpop_t + \beta_4 Inrn_t + \beta_5 \Delta\ tmp_t + \varepsilon_t \qquad \text{(x)}$$

Where:

β_0 deotes the intercept term.

$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ (are variable coefficients and) denote parameters to be estimated. The subscripts denote successive time periods.

Iny_t denotes the natural logarithm of real GDP per capita for time period *t.*

Ink_t denotes the natural logarithm of real gross fixed capital formation (US dollars).

$Inhnc_t$ denotes the natural logarithm of gross secondary school enrolment rate for time period *t.*

$Inpop_t$ denotes the natural logarithm of total population for time period *t.*

$Inrn_t$ denotes the natural logarithm of total rainfall for time period *t.*

$\Delta\ tmp_t$ denotes annual (computed) temperature change for time period *t.*

ε_t denotes a random disturbance term for time period *t.*

3.3 Definition and Measurement of Variables

3.3.1 Real gross fixed capital formation

This study used the real gross fixed capital formation. This is the net increase in physical assets and is given on annual basis.

3.3.2 Gross secondary school enrolment ratio

The study used gross secondary school enrolment rate. This is the total number of individuals enrolled in secondary school, not taking into account of their ages, divided by the number of individuals that officially should be enrolled in the secondary school, taking into account of their age.

3.2.3 Total Population

The study used the total population data which is the measure of the number of individuals in a country regardless of their citizenship change over an observed time period, usually, one year.

3.3.4 Total rainfall

The study used the total rainfall received in Kenya data. This is computed by summing the monthly averages on annual basis. This gives the total annual amount of rainfall that is received in millimetres.

3.3.5 Change in Temperature

The study used the change is temperature; which is computed by taking the difference between the highest and the lowest atmospheric degree of hotness on annual basis, measured in degree Celsius.

3.3.6 Dependent variable

The study used the real GDP per capita growth as the dependent variable, denoted as y, which is measured in US dollars. Usually, the GDP per capita growth is the monetary value of a given economy, which is computed by dividing that value as an annual percentage. This indicator is estimated by assuming losses attributable to depreciation or/and 'wear and tear' of the country's natural resources.

Table 3.4. Summary of variables and expected signs

Variable	Notation	Expected Sign	Source
GDP per capita growth	y	Dependent variable	WDI
Real gross fixed capital formation	k	Negative	WDI
Gross secondary school enrolment rate	hnc	Positive	WDI
Population growth rate	pop	Negative	WDI
Rainfall	rn	positive	WB climate change Portal
Change in temperature	Δtmp	Negative	WB climate change portal

3.4 Econometric approach

In exploring the link between weather variability and economic growth, time series data is used. Real GDP per capita, is the dependent variable in the model, is regressed against the fixed capital formation, population growth rate, secondary school gross enrolment ratio, change in temperature and annual average rainfall, which are a set of independent variables. In order to know if there is long-run relationship among variables under consideration or not, the ordinal least square (OLS) method is used to estimate the parameters under consideration using the model below:

$$y_t = \propto + \vartheta_0 X_t + \epsilon_t \qquad \text{(xi)}$$

Where, y_t is the real GDP per capita, $\propto$ and ϑ are parameters to be estimated while X_t denotes a set of independent variables under consideration and ϵ_t is the disturbance term whose mean is zero estimates the effect of the omitted variables in the regression. Since majority of the time series data exhibit non-stationarity, it is important that measurement tests are carried out. This is because non-stationary data series leads to spurious effect on outputs. As a consequence, the t-statistic as well as the F-test becomes inconclusive. It therefore necessitates the following tests to be performed.

3.4.1 Normality test

This test is important in time series. It establishes whether the disturbances are normally distributed or not. If a constant is included to a normally distributed variable, the nature of distribution of that variable is not altered but moves along the horizontal axis. Above all, all normally distributed linear variables exhibit a normal distribution. To determine the normality of the disturbances, the Parzen-Rosenblatt window approach is used alongside the lvr2plot that helps to determine outliers.

3.4.2 Stationarity test

A time series dataset is said to be stationary if:

$$E(X_t) = \text{ constant} \; \forall \; t \in X \tag{xii}$$

$$Var\ (X_t) = \text{ constant} \; \forall \; \text{t} \; \in \text{X} \tag{xiii}$$

$$Cov\ (X_t, X_{t+j}) = constant\ \forall\ t \text{ and } \forall\ j \neq 0 \tag{xiv}$$

A time series (dataset) is said to be stationary if its mean, variance as well as the covariance exhibit constancy over time. A time series (dataset) that does not meet the above three conditions is said to be non-stationary, which allows variable estimates to vary resulting to spurious regression the spurious correlation problem. Since spurious estimates are a problem, there is need to make the non-stationary data stationary so as to come up with reliable results before regression is done. If results suggest the presence of the unit roots, the dataset are made stationary by differencing (Thomas, 1997).

3.5 Post-estimation tests

The OLS estimation procedure requires that conditions for the resultant residuals are satisfied. In this study, the following tests will be considered.

3.5.1 Autocorrelation test

Autocorrelation, also known as serial correlation, is synonymous when dealing with time series. It occurs when covariances as well as correlations become non-zero between error terms under consideration. In time series data, there is a possibility for a 'spill-over' of random shocks from one time period to another. For instance, weather variability can generate these shocks in time series. These shocks (positive or/and negative disturbances) unobservable are. But with the help of a plot of residuals against time, residual patterns can be established. Presence of autocorrelation makes the OLS estimators consistent and unbiased but asymptotically inefficient. Above all, the OLS equation for estimating the variances of estimators may become biased and consequently invalidate the common OLS inferential approaches (Thomas, 1997). It is in this regard that the Pearson moment-product serial correlation will be employed.

3.5.2 Heteroskedasticity

Heteroskedasticity is said to occur when the disturbance variances are non-constant. If there is a large variation in the size of the sample, then heteroskedasticity will occur. The existence of this phenomenon violates an OLS assumption, which is homoskedasticity.

Heteroskedasticity violates the property of minimum variance of OLS approach, affects the hypothesis testing and renders the OLS approach inefficient. Two properties that makes this test important is because it does not assume prior knowledge of heteroskedasticity and that it is not depended on normality assumption such as the Cook-Weisberg test (Thomas, 1997). In this study, both the White's test and the Cook-Weisberg tests for heteroskedasticity will be carried out.

3.5.3 Cointegration test

This test is carried out in order to ascertain long-run relationships among variables under consideration. Because we are dealing with a multivariate case, measurement of long-run relationships may be linked by more than just a single cointegrating vector (Thomas, 1997; Johansen, 1988; Johansen and Juselius, 1990).

3.6 Data Type and Sources

Secondary time series dataset for the period 1964 to 2013 for was utilised in this study. The real GDP per capita, the gross real capital formation, population growth rate and data on secondary school enrolment rate was assembled from the WDI. The meteorological datasets for temperature and rainfall were assembled from the WB climate change portal and computations made to come up with changes in temperature. The GDP and the gross real capital formation datasets are computed annually (by the WB) whereas the meteorological data are collected on daily basis across weather stations in the country and remitted from regional stations to KMD where they are aggregated and shared with various international bodies who have interest with the data. Choice of weather variables is very important in investigating its full range impact on overall economic performance. A decision to consider rainfall and temperature as indicators of weather (although a novelty vis-à-vis economic growth) was highly motivated by their vast application by various[6] empirical studies.

[6] Such as Dell *et al.*, (2011), Cocalito *et al.*, (2014), Bloesch & Gourio (2015), Bigano *et al.*, (2005), Mboya (2013) and Hor et *al.*, (2005).

CHAPTER FOUR

EMPIRICAL RESULTS AND DISCUSSION

4.0 Introduction

In this chapter, the statistical techniques for estimation are presented. This includes stepwise tests for time series data which the study employs. First, the normality test then stationarity test and the cointegration tests are presented as figures and tables. After running the regression, the autocorrelation, heteroskedasticity as well as the multicollinearity tests are executed and output discussed into details. A description of data type and source is provided in the latter part of the chapter.

4.1 Descriptive statistics

Ordinarily, economic data may not be normally distributed. Although most datasets exhibit a clear base, the nature of their peaks differs by different scales from the mean, zero. Especially, presence of outliers has potential to vary the distribution of data, negatively or positively. This is not without important effects in estimation results, if tests are not incorporated in the whole procedure.

In this analysis, a dataset with six variables and 50 observations each was considered. First, measures of variability to determine distribution behaviour of data variables under investigation were computed. The mean is computed by summing up a given dataset series and dividing the total by the number of observations within that series. The standard deviation explains the dispersion of a given dataset series. The different between the maximum and the minimum value within a given series gives the range over which given data values are spread whereas the variance estimates the spread of given data entries from their particular mean.

In this paper, normality test for skewness and kurtosis were conducted to determine the nature of distribution of data observations. The Parzen-Rosenblatt window approach, which is a smoothing technique for normality was also executed. This procedure is important in identifying possible transformations that can make data to be normally distributed. The procedure can bring the distribution values of variables closer to normal. While skewness estimates the asymmetrical probability distribution of a given dataset around its mean (0), kurtosis seeks to determine the "tailedness" of any such probability distribution.

Conventionally, the margin of skewness is contained between plus and minus 2. But because the direction of skewness along the base or sign of skewness is important, the value of skewness can determine whether a particular data has a high, moderate or even a symmetrical skew. Since the skewness values for the variables as presented in Table 2 below range between -0.5 to 0.5, they are symmetrical but human capital formation $(Inhnc)$ which has a moderate symmetry and negatively skewed. This suspicion is confirmed by the verity that majority of the variables indicated that they had a medium left tail but for rainfall and change in temperature. Kurtosis for all variables is within the limit but for human capital formation $(Inhnc)$, rainfall (rn) and temperature $(\Delta \text{ tmp})$ which is quite high prompting the need to do some normalization to keep the distribution of kurtosis within the range -3 and 3 though the kurtosis for rainfall within the acceptable limit[7]. The large kurtosis for the fixed capital formation, and rainfall is an indicator that the distribution of these two variables is more peaked with leftward outliers for the gross enrolment ration and rightward outliers for rainfall. These results are as shown on the Table 4.1.

Table 4.1. Descriptive statistics for the GDP per capita, fixed capital formation, gross enrolment ratio, total population, total rainfall and change in temperature.

Variable	Iny	Ink	Inhnc	Inpop	Inrn	Δtmp
Obs	50	50	50	50	50	50
Mean	22.71616	21.10872	13.76439	16.86767	6.475461	0.0168774
Median	22.75272	21.22003	14.05608	16.45428	6.48722	0.0149632
Std. Dev.	1.075029	1.078488	1.193771	0.473229	0.154894	0.3575358
Min	20.72118	18.68673	10.48908	16.03473	6.170293	-0.6903000
Max	24.73243	23.13123	16.09198	17.5927	6.913393	.8980964
Variance	1.55686	1.163136	1.425089	0.223946	0.023992	0.1278319
Skewness	-0.10437	-0.24259	-0.59517	-0.19221	0.337112	0.1943784
Kurtosis	2.390221	2.836409	3.428308	1.769567	3.288476	2.838703

The high kurtosis value for the gross enrolment ratio and rainfall variables necessitated the need to conduct the studentized normalization of residual squares to eliminate polar observations or outliers using the Cook's D procedure that combines both leverage and residual, which was executed to determine the particular polar observations for all variables under investigation. Studentized residuals were also executed to show the highest and lowest observations for all variables entries. This procedure helps to numerically determine the problematic point. As indicated in the Table 4.1, the mean for most variables is not quite

[7] Mardia, (1974) explains that a kurtosis value of 3.4 fall within the acceptable limit.

different from the median but for the human capital formation, which suggests that the distribution for majority of these variables is symmetric.

4.2 Unit root test

The unit root test, which serves to determine the presence or the absence or stationarity in a given dataset was carried out. In that regard, the Augmented Dickey-Fuller method was used to assess for the presence or absence of unit roots in variables under estimation. The test results showed that variables were stationary at level with zero lags and at integration of order 1. The ADF test has three models and consistency in stationarity in output for all the three models is what prompts a variable to be declared as stationary. The test was subjected to the null hypothesis of stationarity. As presented in the Table 4.2, the variables were stationary and significant at 1 percent, 5 percent and at 10 percent under the intercept only, trend and intercept and in the suppressed trend and intercept model.

Table 4.2. Unit root tests results for the GDP per capita, fixed capital formation, gross enrolment ratio, total population, total rainfall and change in temperature.

			Model Type		
Variable notation	Number of lags	Order of integration	Intercept Only	Trend and Intercept	Suppressed trend and Intercept
Iny	0	1	-4.935	-4.882	-3.650
Ink	0	1	-6.827	-6.790	-5.791
Inhnc	0	1	-14.637	-14.504	-14.075
Inpop	0	1	-6.760	-7.108	-6.833
Inrn	0	1	-8.614	-8.518	-8.642
Δtmp	0	0	-9.047	-8.967	-9.107

4.3 Correlation of variables

Correlation is important as it estimates the magnitude of influence among variables under consideration. Most importantly, correlation does not directly imply that variation in one variable, however strong the association might be, necessarily leads to variation(s) in the other variable(s). The correlation test was carried out and variables indicated different but fairly weak association with other variables but capital formation vis-à-vis GDP growth per capita that indicated an association of a higher magnitude among variables under consideration. This prompted the need to use the Pearson correlation procedure to determine the significance of these variables despite the magnitude of their association. The Pearson moment-product correlation was executed among GDP (Iny), capital formation (Ink), GER (Inhnc), total population (Inpop) rainfall (Inrn) and temperature (Δ tmp). The product indicated that the coefficient of determination, r^2, explains variation in GDP by 62 percent for fixed capital formation, GER by 24 percent, and total population by 7.3 percent and rainfall by 13 percent. Rainfall explains total population by just 2 percent while change in temperature explains GDP per capita growth, the fixed capital formation and GER by 16 percent, 3 percent and 22 percent, respectively. Table 4.3 below indicates results for the correlation matrix.

Table 1.3. Correlation matrix for the GDP per capita, fixed capital formation, gross enrolment ratio, total population, total rainfall and change in temperature.

Variable	Iny	Ink	Inhnc	Inpop	Inrn	Δtmp
Iny	1					
Ink	0.6182	1				
Inhnc	-0.2467	-0.0732	1			
Inpop	-0.0731	-0.0388	0.0011	1		
Inrn	0.1318	0.128	-0.1473	-0.0076	1	
Δtmp	0.0279	0.03	-0.0713	-0.012	-0.3734	1

4.4 Prais-Winsten AR(1) procedure

The Prais-Winsten that assumes AR(1) in linear estimations to correct for the problem of serial correlation was also carried out. Upon this diagnostic test, the results suggested significance of the variable determining variability of weather at one percent, five percent and ten percent levels of significance. Results for this procedure are shown in Table 4.4. Equation below expresses the Prais-Winsten AR(1) model that accounts for the serial correlation problem.

Table 4.4. Prais-Winsten AR(1) regression output for the GDP per capita, fixed capital formation, gross enrolment ratio, total population, total rainfall and change in temperature.

Iny	Coef.	Std. Err.	t	P>t	[95% Conf.Interval]	
Ink	0.333805	0.067294	4.96	0.000	0.198095	0.469516
Inhnc	-0.04031	0.024176	-1.67	0.103	-0.08907	0.008442
Inpop	-1.16213	2.763667	-0.42	0.676	-6.7356	4.411334
Inrn	0.018867	0.067808	0.28	0.782	-0.11788	0.155616
Δtmp	0.00139	0.039492	0.04	0.972	-0.07825	0.081033
_cons	0.09312	0.089393	1.04	0.303	-0.08716	0.273397

$$In\ y_t = 0.093 + 0.334Ink_t - 0.040Inhnc_t - 1.162Inpop_t + 0.019Inrn_t + 0.001tmp_t + \varepsilon_t \quad \text{(xv)}$$

4.5 Estimation of the model

The correlation and stationarity tests provided robust outputs to be used as inputs in the estimation, the process was executed and results provided in Table 4.5.

Table 4.5. Regression results for the GDP per capita, fixed capital formation, gross enrolment ratio, total population, total rainfall and change in temperature.

Iny	Coef.	Std. Err.	t	P>t	[95% Conf.Interval]	
Ink	0.344313	0.067423	5.11	0.000	0.208342	0.480285
Inhnc	-0.04125	0.024554	-1.68	0.100	-0.09077	0.008271
Inpop	-1.13917	2.669051	-0.43	0.672	-6.52183	4.243482
Inrn	0.014978	0.068881	0.22	0.829	-0.12393	0.153889
tmp	0.001776	0.039926	0.04	0.965	-0.07874	0.082295
_cons	0.091505	0.086378	1.06	0.295	-0.08269	0.265702

Given the regression results above, most variables were found to be insignificant but the fixed capital formation and the GER that were significant at all levels and at ten percent, respectively. As a result, there was need to carry out more test to determine if the data was cointegrated or had the problem of heteroskedasticity.

4.6 Post estimation tests and results

4.6.1 Heteroskedasticity

Regression results in Table 6 above were presented without testing for heteroskedasticity. First the White's test then the Cook-Weisberg test for heteroskedasticity was carried for confirmation. The null hypothesis is that there is no relationship between the predictor variables and the squared residuals. If there is an association then heteroskedasticity is a serious problem. For these tests, it emerged that there was a substantial amount of heteroskedasticity. To rectify for this problem, robust test was carried out, which gave the corrected and robust standard errors but the p-value consistently indicated that only the fixed capital formation that was significant.

4.6.2 Cointegration test

Upon carrying out the cointegratiopn test under the null hypothesis that there is no cointegration, the Durbin-Watson test was carried out. The results indicated that the variables are all cointegrated.

4.6.3 The vector error correction model results

Since the variables under investigation were found to be cointegrated, this necessitated the need to carry out the vector error correction model (VECM). This model accounts for error corrections in instances where variables under exploration depict long-run deterministic behaviour. The VECM estimation results are as presented in the Table 4.6.

Table 4.6. The VECM estimation results for the GDP per capita, fixed capital formation, gross enrolment ratio, total population, total rainfall and change in temperature.

beta	Coef.	Std. Err.	z	P>z	[95% Conf.Interval]	
Iny	1	.	.	.	.	.
Ink	-0.0396	0.291825	-0.14	0.892	-0.61157	0.532363
Inhnc	-0.20972	0.193748	-1.08	0.279	-0.58946	0.170018
Inpop	-3.05921	7.459115	-0.41	0.682	-17.6788	11.56039
Inrn	-2.58134	0.375621	-6.87	0.000	-3.31754	-1.84514
∆tmp	1.426487	0.195586	7.29	0.000	1.043144	1.809829
_cons	0.021382	.	.	.	.	.

Upon the final estimation, two variables, rainfall and change in temperatrure were found to be significant at 99 percent level of significance. The GER, the total population as well as the fixed capital formation were found to be insignificant. The resulting estimated model was given by:

$$In\ y_t = 0.0214 - 0.0396 Ink_t - 0.2097 Inhnc_t - 3.0592 Inpop_t - 2.5813 Inrn_t + 1.4265 tmp + \varepsilon_t \quad \text{(xvi)}$$

The results revealed that the secondary school gross enrolment ratio (GER), a measure for the human capital formation as argued by Weil *et al.*, (1992), was negatively related to GDP per capita growth. Even though, this finding is consistent with arguments presented by proponents of the decision theory (such as Colacito *et al.* (2015) and Bloesch & Gourio (2015)) who have empirically shown that although advances in technology may be beneficial to overall economic performance of a country, these advances are intricately responsible for the increased CO_2 emissions that has a cost to economic growth.

A unit change of fixed capital formation resulted into a decrease in GDP per capita growth by about four percent. This finding is consistent to that of Zeb (2013) who found that the quantity of capital share is affected by climate change and falls with increases in temperature and ultimately lessens the scale of economic growth.

Change in population and rainfall has even greater impact on economic performance, according to the results which suggest that a unit change in total population and rainfall has potential to spur losses of up to 305 percent and 258 percent in GDP per capita growth. Economic losses as a result of changes in the total population is explained by the neo-Malthusian theory which postulates that an increasing population a given society can undermine food production if means of subsistence are reduced as a result of increased environmental pressures. This is because a big population, especially if it is poor, tends to scramble and over-use environmental endowments. This practice undermines what these endowments can otherwise produce if population explosion is well observed. In this regard, Thornton (2006) has argued that the economic welfare, especially, of the rural population, will not fail to be undermined, adding weight to these study findings. Rainfall, when received on season, is good for agricultural performance and ultimately good for the overall economic performance as argued Van-Passel *et al.* (2012), which is in essence contrary to the study findings. However, Ngecŭ & Mathu (1999) strongly show that continued rains are not without heavy economic losses as this study suggests.

Finally, the results showed that a unit change in change in temperature resulted to about 142 times change in GDP per capita growth. The high magnitude of the effect of change in temperature on GDP per capita growth is best explained by Kabubo-Mariara & Karanja (2007) who have argued that temperature unlike rainfall has greater effect on agricultural performance. This performance has an implication on the overall performance of the economy. But these findings are in sharp contrast with those of Bello & Maman (2015), Zeb (2013) and Colacito *et al.* (2014) who claim that increases (upward changes) in temperature result to possible declines in growth.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

It is apparent that the world is increasingly experiencing rapid environmental changes that are not without important social-economic implications for growth and development. Erratic weather has become a central issue in development particularly for struggling economies like Kenya that are heavily dependent on rain-fed agriculture. Modernisation of agriculture through irrigation is still limited. Weather-sensitive sectors still incur losses that could otherwise be avoided if robust legislation, adaptation and mitigation measures were in place. Funding for safety and precautionary mechanisms can be very costly yet floods and droughts are exacerbating havoc across the country. But how this change in weather influences economic performance is either undermined or not understood given the few empirical studies that have sought to investigate the problem.

This study sought to explore the influence of weather variability on overall economic performance and to contribute in informing policy, given the limited empirical researches in this area. The exploration sought to determine the extent of damage on economic performance as a consequent of unpredictable weather. Based on the findings of this study and contributions from other empirical works, potential areas of research and viable policy formulations that have potential to impact on growth in the face of a weather change are provided.

The findings revealed that the fixed capital formation had a negative impact on GDP per capita growth, overriding theory. The human capital formation had a decreasing contribution on GDP per capita, suggesting quite inconsistent results as Zeb (2013). The neo-Malthusian theory renders this debate unsettled because it attributes progress in the human capital formation to be detrimental to the environment and therefore, rather than to contribute to productivity, to be responsible to environmental degradation that has immeasurable costs over the long-run to economies. Findings on the effect of total population portends to growth were also found to be disadvantageous. These findings are analysed, first by theory then by empirical research. For however much the weather may be hard to forecast as the chaos theory claims, the well being of a society may not be undermined provided its means of subsistence remain bountiful, however much that the population may grow. But this bountifulness in means of subsistence is availed when the environment is favourable for means of production and weather predictable and when rainfall is received on season. Hor *et al.* (2005) using a multivariate model to determine energy consumption, reveal that a big population is a burden to a country as it directly increases energy demands. In addition, because many people have to scramble for increasingly reducing recourses, there is little in their disposal that they can save. Therefore, the neo-Malthusian theory concludes that there is need to contain population if environmental overexploitation is to be controlled.

Findings on the influence of rainfall and change in temperature are inconclusive. The chaos is anchored on this inconclusiveness. This is because weather exhibits indeterminate behaviour. But as these findings suggest rainfall can spur negative effects on economy. Yanda & Muyaba (2011) support these findings in their empirical research. They claim that unprecedented rainfall is largely to blame for the continued malaria and other water-borne diseases incidences. But Ricardian approach studies (such as Van-passel *et al.* (2012), Kabubo-Mariara & Karanja (2007) attribute agricultural best performance to availability of rainfall. Findings on temperature are in sharp contrast to a range of empirical studies. For instance, Nyang'au (2014), Zeb (2013) and Dell *et al.* (2013) in their analysis using the CERES rice model, the OLS method and the IAM technique, respectively, concluded that increased temperature have direct repercussions to economic growth but Bigano *et al.* (2005) who analysed panel data whose findings are consistent with findings in this study.

5.2 Conclusions

The overall conclusion drawn from this study is that weather-sensitive sectors are at risk if adverse effects of weather change continue to manifest. The future well-fare may be jeopardized if synergies are not directed in understanding the potential effects of what weather variability will bring about. Although investment can significantly improve the level of GDP growth per capital and improve the well-being of the people, a fall in rainfall has potential to reduce this performance by reducing means of production and therefore earning, which ultimately reduces savings. But even as production processes continue, technology allows for new ways to produce goods. Some of these new techniques are central in perpetuating the global warning problem. This has far reaching implications on security and on food security, employment and on trade. Inconclusively, this paper makes an attempt to explain that shifts between rainfall and abnormal changes in temperature are not the only way that weather variability can influence economic growth.

5.3 Recommendations and areas for further research

This research paper presents some interesting results upon which recommendations that are geared towards informing policy on areas of interest for further research are revealed. But first and foremost, there is need for assessment of the overall state of infrastructure and wealth and developing pathways so that this wealth can be protected against damage and loss whenever extreme weather is experienced. From the theoretical perspective, weather change exhibits chaos in the sense that it is unpredictable yet it affects so many sectors that are pertinent in improving the people's welfare. It is important to establish the magnitude of these effects through empirical explorations. The weather change-food nexus, weather change-security nexus and weather change-trade nexus are pertinent areas of interest that will unravel the underlying relationships and their impacts in the developing countries context. Lastly, given the uncertainty that overrides weather variation in temperature and rainfall from season to another, there is need for government(s) to create additional risk management basket to cushion the most vulnerable portion of the population against the multifarious weather-induced undesirable shocks. The evidence from this study has indicated that weather variability has huge implication for economic performance. But the economic cost of this implication is scarce.

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