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An Analysis of the Quantitative Impact of Climate Change on National Level Economic Growth: A Kenyan Case Study

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DECLARATION

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the Research Proposal contains no material previously published or written by another person except where due reference is made in the Research Proposal itself.

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ABSTRACT

The issue of climate change has been a growing interest in recent times for a number of reasons. Chief among them is because the economic landscape of most if not all African countries is dependent on the dynamics of climate change. Key sectors of the economy such as agriculture, forestry, energy, coastal and water resources are highly susceptible to climate change. That being the case, this paper seeks to analyze the empirical linkage between economic growth and climate change in Kenya from a quantitative point of view.

Using data from two climate variables, temperature and precipitation, and employing time series analysis techniques, the paper tries to estimate both the short-run and long-run effects of climate change on growth. The paper establishes that an increase in temperature significantly reduces economic performance in Kenya. This takes the form of reducing agricultural output, industrial output, and aggregate investment, and increasing political instability.

Some policy options have arisen from this study all in all. First and most importantly, mainstreaming climate change adaptation into National Development Strategy and budgets could promote proactive engagement on the formulation and implementation of climate change adaptation strategy. Second, the potential of regional or multiple countries approach to climate change adaptation is high due to possibility of economies of scale.

1. INTRODUCTION

1.1 Background Information

In the economic history of the 20th century, environmental issues gradually become more prominent. During the Great Depression of the 1930s soil erosion drew attention, and in the 1950s and 1960s concerns about pesticide use and air pollution emerged. Only in the last decades of the 20th century, however, did environmental degradation gain recognition as fundamental challenge to the whole economic growth process. In the global economy of the 21st century, on the other hand climate-related considerations will be a determining factor in shaping economic development (Stern, 2006).

The climate change debate has been on for quite some time now. But even before, economists and others have been concerned with the link between climate and economic well-being well. In the late 19th century, the British government charged successive scientists in India with predicting the quality of monsoon rains in an attempt to mitigate the devastating effects of drought on the subcontinent. One of these scientists, Sir Gilbert Walker, pioneered the use of correlation coefficients and used them to establish the Southern Oscillation Index (SOI), a pressure differential between Darwin, Australia and Tahiti that still serves as an indicator of the El Nino/Southern Oscillation (ENSO) (Brown, Meeks, & Ghile, 2010).

According to (Stern, 2006) scientific evidence is now overwhelming and climate change is a serious global threat and demands an urgent global response. It will affect the basic elements of life for people around the world: access to water, food production, health and the environment. Consequently, hundreds of millions of people could suffer hunger, water shortages and coastal flooding as the world warms.

As one of the more contentious issues, it has left the global economy in a rather pernicious state. More specifically, the nexus between continued economic growth and environmental sustainability (Alagidede, Adu, & Boakye, 2014). The pessimistic view is that continued growth is incompatible with environmental sustainability since the growth process requires the use of the environment in two ways. As a source of energy and raw materials and as a sink for the wastes that are a by-product of the production process (solid, gas and liquid). This shows that the production process is injurious the environment and climate change comes as a result. Paradoxically, climate change has been linked with reduced national productivity. According to this school of thought, environmental sustainability is possible only if growth is halted (Alagidede, Adu, & Boakye, 2014) .

Nonetheless, the positive school of thought is for the idea that continued economic growth need not be incompatible with environmental sustainability in a world of continuous technological change. This view emphasizes the importance of using green technologies and other alternative ways of production and consumption that do not compromise economic growth both in the medium- to long- term (Alagidede, Adu, & Boakye, 2014). Thus, a concerted global effort that takes into account cost-effective instruments of mitigating the effects of rising global temperatures would in the end promote, and not harm economic growth. Ostensibly, there is a relationship between climate change and economic growth.

In order to appreciate the idea of economic growth and climate change, it would be worthwhile to understand the concepts and contexts in which they have been applied in the conducting of this research. There is a general consensus on what is implied by economic growth. (Acemoglu & Robinson, 2012) define economic growth as the increase in the inflation-adjusted market value of the goods and services produced by an economy over time. It is conventionally measured as the percent rate of increase in real gross domestic product, or real GDP, usually in per capita terms.

Climate change can be understood as the change in the statistical distribution of weather patterns when that change lasts for an extended period of time (i.e., decades to millions of years). Climate change may refer to a change in average weather conditions, or in the time variation of weather around longer-term average conditions (i.e., more or fewer extreme weather events). Climate change is caused by factors such as biotic processes, variations in solar radiation received by Earth, plate tectonics, and volcanic eruptions. Certain human activities have also been identified as significant causes of recent climate change, often referred to as global warming. For the purpose of this research therefore, the concepts of climate change and economic growth should be interpreted in that light.

As stated earlier, climate change has been identified as one of the most daunting challenges facing the world in this century and has been noted by many a scholar to be particularly more serious in developing countries arguably due to their large geographical exposure, low incomes, greater reliance on climate-sensitive sectors and weak capacity to adapt to the changing climate dynamics (Odusola & Abidoye, 2006).

Arguably, the economic landscape of African countries like Kenya are almost entirely dependent on the dynamics of climate change. By and large, African economies are driven by the key sectors of agriculture, forestry, energy, tourism, coastal and water resources. It goes without saying that these are most susceptible to climate change. Another predisposing factor is the geographical location of Kenya and most African countries. Being located on the lower altitudes has already put the region at a disadvantage where about 80 percent of damages from climate change are concentrated (Mendelson, The Impact of Climate Change on Agriculture in Developing Countries, 2008). It goes without saying that further warming could affect aggregate productivity immensely.

(Lanzafame, 2012) indicates in his study that countries in Sub-Saharan Africa, of which Kenya is gladly a member, would bear the brunt of climate change. This is as opposed to more developed economies. The overwhelming reliance on agriculture and other climate-sensitive sectors for production as well as the limited capacity to respond appropriately to climate related shocks tend to expose the African continent to the vagaries of extreme weather conditions. Ignoring the climate change issue will result to aggregate risks and costs that are equivalent to 5% of global GDP infinitely (Stern, The Stern Review Report: The Economics of Climate Change, 2006).

Evidences indicates that the Carbon Dioxide content of the atmosphere could double by the middle of the current century and that climate change has already begun. Measurement records indicate an increase of 0.6±0.2°C in global average temperature since the late 19th century. If nothing is done to reduce emissions, current climate models predict a global warming of about 1.4-5.8°C between 1990 and 2100 (Intergovernmental Panel on Climate Change., 2007). Carbon dioxide is the most significant one, accounting for 49% of global warming.

Over the past five decades (1960-2009), many African countries Kenya included have experienced substantial rise in temperature with a significant reductions in precipitation. The rises in temperature have been to the tune of 1 degree Celsius to over 3 degrees Celsius (Odusola & Abidoye, 2006). As articulated by Earth trends (2009), African emissions are less than 5% of total carbon dioxide-equivalent emissions and this share is expected to grow in the near future. This knowledge provides incentives for Africa and more so Kenya to understand the costs of climate change to its economy and development prospects with a view to informing policy decisions.

This is not only as a result of losses to the economy that might be linked to reduced agricultural productivity and labour losses but also from increases in morbidity, mortality and social instabilities. These indirect impacts such as death and disabilities associated with climate change have irreversible economic and welfare consequences. When countries spend some resources to adapt to climate change, they incur opportunity costs of not spending it on research and development and capital investment (e.g. infrastructure) that is a binding constraint to growth and development (Odusola & Abidoye, 2006).

Going by the aforementioned therefore, there is a strong correlation between climate change in the Kenyan economy and this paper seeks to quantify the extent to which climate change can influence the economic growth. Notably, changes in the real GDP. In focusing on Kenya, it is possible to obviate some of the nuances that are left undetected in the global debate and contribute to the search for policy interventions at the national level.

Of great importance to the study is the over-reliance of Kenya on rain fed agriculture. Kenya is a frontier market but one of the Least Developed Countries nonetheless with about 42% of the population of 44 million living below the poverty line (United Nations Development Program, 2009). Its Human Development Index (HDI) is 0.555; ranking 146th out of 182 countries (United Nations Development Program, 2009). Consequently, poverty which is associated with high population growth, low level of social institutional setups and backward technology employed is the main social challenge to sustainable development in the country (World Bank, 2008).

As in most developing countries, the Kenyan economy is dominated by the agricultural sector which can in turn affect other sectors via the value chain system. However, the performance of the agricultural sector has been weak due to factors such as traditional farming practices and climate related problems. The country's climate is characterized by a history of climate extremes and changing trends in temperature and precipitation patterns.

In line with the importance of agriculture to the Kenyan economy, it is the mainstay of the Kenya's economy. The sector directly contributes 24% of the Gross Domestic Product (GDP) and 27% of GDP indirectly through linkages with manufacturing, distribution and other service related sectors. Approximately 45% of Government revenue is derived from agriculture and the sector contributes over 75% of industrial raw materials and more than 50% of the export earnings. The sector is the largest employer in the economy, accounting for 60 per cent of the total employment. Over 80% of the population, especially living in rural areas, derive their livelihoods mainly from agricultural related activities. Due to these reasons the Government of Kenya has continued to give agriculture a high priority as an important tool for promoting national development (Kenya Agricultural Research Institute, 2012).

That being the case, climate change is a major issue insofar as the Kenyan economy is concerned. This is also not forgetting the geographical placement of Kenya as well. Economic costs of climate change impacts have been estimated to be several percentages of GDP if no measures are taken either to adapt or mitigate the effect of climate change (Stern, 2006).

Thus, decision makers need to plan for these impacts through investment in mitigation and adaptation policies with the respective aim to reduce emissions of greenhouse gases (GHGs) and to avoid damages of climate change for the betterment of environment and societal well-being.

1.2 Problem Statement

The climate change issue is one of the major problems of the 21st century. Its effects on the global environment are critical to the human welfare function. Though the least developed countries in general and Africa in particular contribute the least to the problem, they are the most affected. This is because for reasons varying from lacking resources to scope, rampant poverty and most of them are located in regions where severe weather will hit the most. More so, the geographical placement of Sub Saharan countries has been flagged as a major issue. This puts Sub Saharan Africa (SSA) at the brunt of the climate change conundrum. This makes it difficult to deal with the problem of climate change via unilateral efforts or even efforts of a certain group of countries. The world needs to acts globally. This is because climate change is a universal or global issue. Human beings are likely to face climate change directly or indirectly and their welfare is negatively affected. The problem of global warming via Green House Gas effect is complicated as it involves the entire world and has no geographical demarcation (Intergovernmental Panel on Climate Change., 2007). Given its massive and disproportional effect, the issue of climate change is no longer a futuristic-like discussion in Kenya. It is an issue that has to be nipped in the bud.

Industrialized countries contributed to 80% of the total atmospheric C02 building and their share of annual CO2 emissions is 60% (Saha, 2010). This implies that though the Least Developed Countries like Kenya contribute the least to the problem, they are the most affected. The problem is further compounded by existing poverty, weak economic development and explosive population growth. This is especially true for Kenya since the country's inhabitants are very vulnerable to the impacts of climate change.

Agriculture remains to be one of the most vulnerable sectors to the estimated changes in climatic conditions despite the technological advances achieved in the second half of the 20^{th} century. Projected changes in temperature and rainfall patterns are likely to have significant effects on potential production. However, the effect of climate change is unevenly distributed across regions of the world. For instance, low-latitude and developing countries are expected to be more adversely affected due to their exposed geography where as high-latitude countries are expected to benefit in terms of crop production (Brown, Meeks, & Ghile, 2010).

(Cline, 2007) predicted that global agricultural productivity will be reduced by 15.9% by the 2080s under the customary warming rate, with developing countries experiencing disproportionately large decline of 19.7% of its total agricultural production. The African continent is expected to experience the burden of these losses, which are attributed to the technological, resource and institutional constraints imposed on economic growth-GDP. As one of the developing nations, Kenya is expected to bear the burden of climate change effects.

The impact may be worsened by its dependence on rain-fed agricultural production, high population growth, insufficient climate related information and poverty, which significantly reduces the capacity to mitigate, adapt or cope with the various effects of climate change.

Although it is vulnerable to climate change, agriculture still remains by far the most important sector in Kenya being a central tool towards economic growth and most economic activities are dependent on agricultural expansion. In Kenya alone, over 80% of the population, especially living in rural areas, derive their livelihoods mainly from agricultural related activities, making the sector the largest in the economy accounting for 60% of the total employment. The contribution to the real GDP per capita is approximately 51% when both direct and indirect effects come into play (Kenya Agricultural Research Institute, 2012).

As a result, any shock related to climate change on this sector would have wider economic impacts on other sectors via the value chain system that can be felt both at micro and macroeconomic levels. Therefore, researching on this issue is critical to contribute for the progress of balanced growth.

Earlier analyses such as (Curriero, Karlyn, & Samet, 2002) delve into the effect of temperature on mortality of certain states in the United States of America. They link high temperatures to increased mortality. (Jacob, Lars, & Moretti, 2007) and (Field, 1992) look into the effect of temperature on crime by analyzing incidences of criminal behavior between 1992 and 2007. Another analysis of the effect of temperature was done by (Miguel, Shanker, & Ernest, 2004) when they analyzed how it influences conflict and drought. All the factors that have been mentioned have either a direct or indirect effect on economic activity and performance. However, the aggregate effect of temperature and precipitation on economic activity has not been analyzed.

Therefore, other than considering individual factors and summing up subsequently, temperature and precipitation data is combined into a dataset and analyzed against the single measure of economic growth. This approach estimates the effect of short-run climate fluctuations using relatively few assumptions. It examines aggregated outcomes directly, rather than relying on prior assumptions about what mechanisms to include and how they might operate, interact, and aggregate.

Finally, it has been shown that there is limited empirical analysis on the damaging effects of climate change on the Kenyan economy. As a result, there is yet to be some sort of convergence on the magnitude of its impact on economic growth. This paper aims at quantifying the implications of climate change on economic growth in Kenya.

1.3 Research Questions

1. Does temperature matter in the analysis and prediction of economic growth?
2. Is there a relationship between temperature and GDP as well as precipitation and GDP?
3. Can the effect of climate change on economic growth be quantified and to what extent has climate change influenced the economic growth of Kenya?

1.4 Research Objectives

1. To determine the extent to which climate change has influenced the GDP of the Kenyan economy.
2. To determine the importance of temperature in the analysis and prediction of economic growth.
3. To suggest policy options which enable to manage or control climate-related impacts on economic growth at country level.

1.5 Justification of the Study

In view of the ongoing debate of climate change and economic growth, it is important to understand the relationship that may exist between the two variables under study and to what extent. This research interest has been intensified by the rising concerns of global warming and whether or not the nexus between economic growth and environmental sustainability can come to a compromise. In similar vein, whether or the gains from environmental exploitation override those from environmental conservation. It is hoped that the results of this study provide these crucial answers for the sake of policymakers in Kenya, all for the betterment of the Kenyan economy both in the short-run and long-run.

2. LITERATURE REVIEW

2.1 Conceptual Framework of Climate Change

Few natural phenomena have attracted the attention of so many scientific fields or elicited so many hypotheses as have climate changes. The possibility that different causes active at different time scales adds to the challenge. One of the simplest and most persistent holds that the sun is a variable star and that the changes in the kind and amount of energy emitted alter the solar constant. A full understanding of the climate system and explanations of past climates logically lead to prediction of future climate (Critchfield, 2003).

Various statistical probabilities can be calculated for broad applications in long-range planning of human affairs. In view of the impact of climate on human activities, it is logical to inquire whether manipulation of the climate system might produce benefits or disasters for humanity. We have the capacity to manage microclimates for the benefit of ourselves, but we also alter them to the detriment of living things and neighbors. For instance, cutting of forests reduces the amount of rain and alters the process of evapo-transpiration and runoff as well as the flow of air. In contrast, irrigation and the creation of windbreaks are representative agricultural practices that influence microclimates (Alagidede, Adu, & Boakye, 2014).

Climate, which we live in, affects everyone on earth in one way or another. The changing climate is a challenge for both current and future generations. Thus, reliable climate information is vital in order to make appropriate decisions in all aspects of human involvement. In line with this reality, changes in climate should be given due attention before it is too late for the Earth to recover. Climate change is an alteration in the state of the climate that can be identified by changes in mean and/or the variability of its properties, and that persist for an extended period, typically decades or longer (Lavell, Diop, & Hess, 2012). Therefore, anticipating the swings of climate is important for ensuring sustainable and balanced economic growth in these times of increasing pressure on the earth's limited resources.

As the scientific consensus grows that significant climate change, in particular increased temperature and precipitation pattern, is very likely to occur over the last 21st century (Jen & Hewitson, 2007), economic research has attempted to quantify the possible impacts of climate change on economic growth. Ignoring climate change issue will eventually damage economic growth. The damages from climate change will accelerate as the world gets warmer. Thus, tackling climate change is the pro-growth strategy for the long-term balanced economic growth. The earlier effective action is taken, the less costly it will be. As the same time, taking measures to help people adapt climate change are essential. Likewise, the less mitigation we do now, the greater difficulty of continuing to adapt in the future.

There is no question or it is evident that the continued buildup of greenhouse gases will cause the earth to warm (Intergovernmental Panel on Climate Change., 2007). However, there is considerable debate about what is the sensible policy response to this problem. Economists, weighing cost and damages, advocate a balanced mitigation and adaption program that starts slowly and gradually becomes more severe over the century. Scientists and environmentalists, in contrast, advocate more extreme near-term mitigation policies. Which approach is followed will have a large bearing on economic growth. The balanced economic approach to the problem will address climate change with minimal reductions in economic growth.

The more aggressive the near-term mitigation program, however, the greater the risk that climate change will slow long-term economic growth. It should be understood that climate is not a stable unchanging phenomena even when left to natural forces alone. There have been several major glacial or cold periods in just the last million years. These natural changes have had major impacts on past civilizations causing dramatic adaptations and sometimes wholesale or general migrations. Climate change is not new. Human-induced climate change is simply an added disturbance to this natural variation. The heart of the debate about climate change comes from a number of warnings from scientists and others that give the impression that human-induced climate change is an immediate threat to society (Stern, 2006). Millions of people might be vulnerable to health effects and crop production might fall in the low latitudes, water supplies might decrease, precipitation might fall in arid regions, extreme events will grow exponentially, and between 20-30 percent of species will risk extinction (Intergovernmental Panel on Climate Change., 2007) and (Stern, 2006). Even worse, there may be catastrophic events such as the melting of Greenland or Antarctic ice sheets causing severe sea level rise, which would inundate hundreds of millions of people.

Proponents or advocates argue that there is no time to waste. Unless greenhouse gases are cut dramatically today, economic growth and well-being may be at risk (Stern, 2006).

Climate change being a real threat to our planet is widely recognized both in the developed and developing countries from social, economic and environmental perspectives. Ever since the wide recognition of the adverse impact of climate changes, there have been a number of related international treaties and conventions in place. Though economic analysis of climate change is comparatively new issue, numerous studies have estimated the impacts of climate change on economic growth-GDP in different regions of the world. In Zambia, for example, 0.4% loss of growth occurred annually between 1977 and 2007 due to climate variability and the accumulated cost for this period was US$ 13.8 billion (James & Tingiju, 2009).

Though most of such studies are numerical in nature and a bit speculative, they provide a solid baseline for other researches to be carried out in the area. Due to climate change the size and composition of countries' GDP may change. Climate change also affects the long-term growth potential of the country. According to (Stern, 2006), in the next fifty years world temperature is expected to raise 2-3 degrees Celsius. This increase will have severe consequences on economic development as it will affect water quality, agricultural productivity and human health. It leads to a loss of 5 percent global GDP per annum.

(Dell, Jones, & Olken, Temperature and Income: Reconciling New Cross-Sectional and Panel Estimates. , 2009) found that due to climate change the growth rate of poor countries would be reduced by 0.6 to 2.9 percentage points. On the other hand according to (Fankhauser & Tol, 2005), climate change affects capital accumulation and people's propensity to save, which in turn reduces economic growth- real GDP. By using different growth model specifications, it was found that dynamic/indirect effects are relatively larger than that of static/direct impacts of climate change. As temperature and precipitation are direct inputs in agricultural production, many scholars in the area believe that the largest effects of climate change will be on agriculture. Climate change can affect food systems in various ways, such as imposing direct impact on crop production through changes in rainfall pattern leads to drought or flooding, whereas warmer or cooler temperatures will change the length of the growing season. Both of them will have the potential to affect food prices and the economics of supply chain.

Environmental regulations are generally perceived to impose constraints on production, which lead to harmful impacts on economic growth. However, it has been argued that the effects of environmental policy on economic growth vary through the stages of development (Smulders & Egli, 2011). Such regulations will enhance the prospects for growth when improved quality increases the productivity of inputs. This is because environmental regulation promotes pollution abatement activities, increasing returns to scale and such regulations can also estimate innovations.

In line with this reality, (Greiner, 2004) has found that an increase in greenhouse gas emissions will negatively affect the aggregate output and the marginal productivity of capital and those higher abatement activities might reduce Green House Gas emissions and lead to higher economic growth. Besides, (Fankhauser & Tol, 2005) have argued that Green House Gas emissions would seriously affect economic development and called for a higher carbon tax to reduce the emissions at the level where there is no an exaggerated magnitude of economic loss.

Growth in terms of sustainability refers to increasing or non-decreasing environmental quality and natural resource depletion and continuous growth in per capita income (Brock & Taylor, 2005). Beyond the basic links between economic production and environment, the links between economic growth, environment and climate change are highly complex, multidimensional and dynamic. Simply put, the links are far from straight forward; simple universally valid truths.

Recent research has gone beyond the statistical artifacts which may indicate a certain functional relationship between growth and environment, and showed that several political economy and governance issues are key determinants to a country's growth path and environmental quality. The difference in inequality such as income inequality produces a gap between the country's ability to pay for the environmental protection and a total willingness to pay (Ali, 2012).

For many pollutants the time series data is rather short and of varying quality, which contributes to the difficulties in making reliable predictions of varying quality.

2.2 Theoretical Reviews

There is a strong and two way interrelationships between climate change and the volume of agricultural production. Climate change can affect agricultural production in a variety of ways. Temperature and precipitation patterns, extreme climatic conditions, surface water runoff, soil moisture and Carbon dioxide concentration are some of the variables which can considerably affect agricultural development (Zhai & Zhuang, 2009).

Their studies concluded that the relationship between climate change and agricultural production is not simply linear. There is usually a certain level of threshold or limit beyond which the sector may be adversely affected. For instance, (Intergovernmental Panel on Climate Change., 2007) reports that warming of more than 3°C would have negative impacts on agricultural productivity globally. However, there is a marked difference regionally with regard to the threshold level- ranging from low to high latitudes. The changes in precipitation and temperature can directly influence crop production. Moreover, they might alter the distribution of agro-ecological zones.

In most of African countries, there is a strong association between GDP growth and climate variables. This resulted owning to lack of economic diversification and strong dependence on the agricultural sector. The root of the matter is that, in Africa, this association is a direct reflection of the very high dependence of agricultural production on climate variables. Specifically to Kenya, climate change affects agricultural production through shortening of maturity period, affecting animal health, growth and reproduction, changing distribution of diseases, changing decomposition rate, expansion of tropical dry forests and the expansion of desertification (World Bank, 2008). In Kenya, such a relationship is very striking. Agricultural output is highly pronounced even by change in a single climate variable such as rainfall, i.e. reduction in its amount. The same is true for the country's GDP as it heavily relies on agricultural sector (World Bank, 2008).

This effect of climate variability is attributed to the fact that those changes can seriously depress agricultural production in the country. Precipitation patterns determine the availability of freshwater and the level of soil moisture, which are critical inputs for agricultural production. Moderate precipitation may reduce the yield gap between rain-fed and irrigated agriculture by reducing crop variability. However, heavy precipitation is very likely to result in soil erosion and difficulty to cultivate land due to water logging of soils. Thus, taken as a whole, it will adversely affect agricultural production (Intergovernmental Panel on Climate Change., 2007).

The aforementioned evidence demonstrates that economic growth in general and households' welfare in particular are still significantly influenced by changes in rainfall and other climate variables. Furthermore, the impact of climate change in the country can be felt not only on agricultural output but also on other sectors of the economy including the country's trade patterns, incomes, consumption and welfare of households through the economics of value chain framework (World Bank, 2008).

However, economic theory does not give us reason to be optimist about pollution. Because those who pollute do not bear the costs of their pollution, an unregulated market leads to excessive pollution. Likewise, there is nothing to prevent an environmental catastrophe in an unregulated market. For example there is some critical level of pollution that would result in a sudden and drastic change in climate. Conceptually, the correct policy to deal with pollution is straightforward. We would estimate the dollar value of the negative externality and tax pollution by their amount. This would bring private and social costs in line, and result in the socially optimal level of pollution. Though describing the optimal policy is easy, it is still useful to know how severe the problems posed by pollution are. In terms of understanding economic growth, we would like to know by how much pollution is likely to retard growth if no corrective measures are taken.

There are two most commonly and widely used approaches for analyzing the impact of climate change. These are the enumerative approach and the dynamic approach. In the former approach the economic impacts of climate change are analyzed separately sector by sector, such as agriculture, manufacturing and service sectors. The effects are possibly evaluated together to obtain an estimate of the total change in social welfare stemming from climate change (Nordhaus, 2006). In this approach, the impacts of climate change are analyzed by emphasizing only one period social accounting matrix (SAM). Unfortunately, intertemporal effects are ignored. This approach also ignores the significant "horizontal interlinkages", such as the interaction of sectorial effects. It mostly uses computable general equilibrium models (CGE) and simulations. Consequently, studies based on this approach have failed to provide information on how climate change may affect growth / welfare in the long run.

In the dynamic approach different specifications of growth models are used by incorporating the damage function. For instance the Solow-Swan and Ramsey-Cass-Koopmans models are the most widely used growth models for analyzing the impacts of climate change on economic growth. (Mankiw, Romer, & Weil, 1992) propose a model that is used less in the analysis of such scenarios. In all these three models, under the assumption of a constant savings rate it is found that if climate change (increase in temperature & irregular pattern of rainfall) has a negative impact on output, then the amount of investment will also be reduced. In the long run capital stock and consumption per capita will decline, which in turn will result in shrinking aggregate demand and will adversely affect countries' GDP.

2.2.1 Theoretical Model

(Dell, Jones, & Olken, Temperature and Income: Reconciling New Cross-Sectional and Panel Estimates. , 2009) incorporated the climatic variables in the production function of their model. The model provided theoretical basis for incorporating climate change into growth equations and the guidelines for decomposition of the impacts of climate change on economic growth-GDP.

Consider a growth function:

$$Y_{it} = e_{it}^{\alpha T} A_{it} L_{it} K_{it} \text{ .... Equation (1)}$$

$$\frac{\Delta A_{it}}{A_{it}} = g_i + \beta T_{it} \text{ .... Equation (2)}$$

Where Y = real gross domestic product/ RGDP

L = labor force/population

A = technology or labor productivity

T= impacts of climate change;

g = growth rate of capital

K = human capital

i = countries or regions under the panel data

t = stands for the time period (t=l, ...,T) ;

e = constant (2.7132)

Note that Equation (1) captures direct or static effects of climate change on economic growth, i.e. it directly relates climate change to GDP whereas Equation (2) captures the indirect or dynamic effect of climate change on economic growth such as the impacts of climate on other variables that indirectly influence GDP.

After taking logarithms of equation (1) and differencing with respect to time, the third equation can be derived:

$$g_{it} = g_i + (\alpha + \beta)T_{it} - T_{it-1}$$

Where g_i the growth rate of output, direct effects of climate change on economic growth appear through α and indirect effects appear through β while g_i denotes the fixed effect.

2.3 Empirical Reviews

Economic research on climate impacts has long revealed that only a limited fraction of the market economy is vulnerable to climate change: agriculture, coastal resources, energy, forestry, tourism, and water. These sectors make up about 5 percent of the global economy and their share is expected to shrink over time. Consequently, even if climate change turns out to be large, there is a limit to how much damage climate can do to the economy. Most sectors of the global economy are not climate sensitive (Romer, 1986).

The economies of some countries are more vulnerable to climate change than the global average. Developing countries in general have a larger share of their economies in agriculture and forestry. They also tend to be in the low latitudes where the impacts to these sectors will be the most severe. The low latitudes tend to be too hot for the most profitable agricultural activities and any further warming will reduce productivity. Up to 80 percent of the damages from climate change may be concentrated in low-latitude countries (Mendelson, Apuvra, & Dinar, Country- specific market impacts of climate change, 2001).

Since there are no market prices to use as guides, economists interested in pollution must begin by looking at the scientific evidence. For example, in the case of global warming, a reasonable estimate is that in the absence of major intervention, the average temperature rise by 3 degrees Celsius over the period 1990-2050, with various effects of climate change (Nordhaus, 2006).

Economists can help estimate the welfare consequences of these changes. After considering the various channels through which global warming is likely to affect welfare, (Nordhaus, 2006) concludes that a reasonable estimate is that the overall welfare effect as of 2050 is likely to be negative-the equivalent of a reduction in GDP of 1 or 2 percent. This corresponds to a reduction in average annual growth over the period 1990-2050 of only about 0.03 percentage points. Not surprisingly, it is found that drastic measures to combat global warming such as policies that would largely halt or end further warming by cutting emissions of Green House Gases by 50 percent or more would be much more harmful than simply doing nothing.

Using a similar approach, (Nordhaus, 2006) concludes that the welfare costs of other types of pollution are larger, but still limited. His point estimate is that they will lower annual growth by roughly 0.04 percentage points. Of course, it is possible that this reading of the scientific evidence or this effort to estimate welfare effects is far from the mark. It is also possible that considering horizons longer than the 50 or 100 years would change the conclusions substantially. But the fact remains that most economists who have studied environmental issues seriously, even ones whose initial positions were sympathetic to environmental concerns, have concluded that the likely impact of environmental problems on growth is at most moderate.

On the basis of the aforementioned theoretical model and empirical propositions, the following reduced form equation/model of growth following a time series pattern can be formulated and estimated:

$$Y_t = \beta_0 + \beta_1 POP_t + \beta_2 HC_t + \beta_3 TEMP_t + \beta_4 RF_t + \varepsilon_t$$

Where:

Y_t represents GDP growth rate

POP_t = population time series

HC_t = human capital time series

$TEMP_t$ = temperature time series

RF_t = rainfall or precipitation time series

ε_t = stochastic error term

The above econometric model is adapted from Solow-Swan and Ramsey-Cass- Koopmans (RCK) growth models. The selection of an indicator or proxies for climate change is a critical issue. In this regard, Green House Gas emission levels, atmospheric Green House Gas concentration levels, global mean temperature, sea level rise and intensity or frequency of extreme events are the most commonly used indicators. As such, detection of proxies for climate change and attribution to causes plays a pivotal role in climate policy making.

Despite the fact that analysis on Kenya has been done before (Odusola & Abidoye, 2006), they face the limitation of focusing their attention on specific crop productivity across agro ecological zones as a function of seasonal variation on climatic variables. As such, they have not linked the climate change issue to the broader context of economic growth as measured by real GDP, which is what this paper seeks to address.

3. METHODOLOGY AND ECONOMETRIC ANALYSIS

3.1 Data and Sources

As the success of any econometric analysis ultimately depends on the availability and accuracy of data, it is paramount to identify the source and nature of data. The study is conducted using a secondary country level macroeconomic data covering the period from 1980 to 2012. For the study of climate change impact on the economic growth, secondary data with time series pattern is used. The data used in this study is collected from various sources which can be grouped into two main categories as data from government organizations and online data bases.

The first category includes the Central Bank of Kenya statistics, the Kenya National Bureau of Statistics, the Kenya Meteorological Department, the Ministry of Finance databases. Online sources include United Nations Development Program (UNDP), World Bank (WB) and Organization for Economic Cooperation and Development (OECD).

This paper examines the effects of temperature and precipitation on a single aggregate measure of economic growth- real GDP. This is done by constructing historical temperature and precipitation data at country level and combines this data set with annual economic growth (real GDP) data and other relevant data to be incorporated in the model.

3.2 Time series Conceptual Framework

A time series involves the sequence of numerical data in which each item is associated with a particular instant in time. An analysis of a single sequence of data is called univariate time series analysis. On the other hand, an analysis of several sets data for the same sequence of time periods is called multivariate time series analysis. The purpose of time series analysis is to study the dynamics or temporal structure of the data. Since time runs forward, time series observations have a natural ordering. This distinguishes time series data from others, because data points close in time are predicted to share more common characteristics than those which are further apart in time (Kao & Chiang, 2000).

One common measure of such characteristics or trends is the correlation of data at different time points. Analysis of time series is the study of the autocorrelation in the data. Such information can help us understand a lot about the time series at hand and make forecast for our data, like forecasting the trend or pattern of macro climate variables - temperature (maximum or minimum) and rainfall distribution for the next week, month or year as well.

Modern investigations may center on whether a warming is present in global temperature measurements or whether levels of pollution may influence daily life. Geographical time series data are those produced by yearly depositions of various kinds can provide long-range proxies for temperature and rainfall. The first step in any time series investigation always involves careful scrutiny/examination of the recorded data plotted overtime. This scrutiny suggests the method of analysis as well as statistics that will be of use in summarizing the information in the data.

(Fankhauser & Tol, 2005) brings forth the argument that a paradigm needs to be devised to clarify climate change as a statistical concept. Climate change is envisioned to involve changes in the location and scale parameters of the probability distribution of a climate variable.

According to (Maddala, 2014), time series analysis can be roughly divided into two types of methods: frequency-domain and time-domain methods. In models underlying the frequency-domain analysis, the time series X_t, is expressed as the sum of independently varying Cosine and Sine curves with random amplitudes.

Time-domain methods are based on direct modeling of the lagged relationships between a series and its past. The methods involve fitting of linear auto regressions and cross-regressions. The time domain approach is motivated by the presumption that correlation between adjacent points in time is best explained in terms of a dependence of the current value on the past values. It focuses on modeling some future value of a time series as a parametric function of the current and past values.

'n scenario, we begin with linear regressions of the present value of a time series on its own past values nd on the past values of the other series. This kind of modeling leads to use the results of the time domain pproach as a forecasting tool and popular with economists. Consequently, this research paper will follow and apply the time-domain method of analyzing a time series data so as to arrive at sound full and contextual economic outputs/outcomes.

3.3 Method of Data Analysis and Estimation Techniques

Since the data used is time series, preliminary tests should be conducted before proceeding to further estimation. The tests include unit root tests and co integration tests. Besides, in order to estimate the long run relationships and short run dynamics simultaneously, vector error correcting model (VECM) is used.

3.3.1 Stationarity and Unit Root Tests

The standard classical methods of estimation are based on the assumption that all variables are stationary. In reality most macro-economic variables are non-stationary at levels (Baltagi, 2008). This oftentimes leads to the problem of spurious regression. Thus, it is necessary to test for stationarity of time series variables before running any sort of regression analysis. Often, non-stationary variables become stationary after differencing and it is possible to estimate using difference of variables if the differences are stationary. But, such a procedure gives only the short-run dynamics and there would be a loss of considerable long-run information.

Given that most economic time series data are non-stationary, the first step is to test whether the variables are stationary or not. Studies have developed different mechanisms that enable non-stationary variables attain stationarity. It has been argued that if a variable has deterministic trend, including trend variable in the regression removes the trend component and makes it stationary (Gujarati, 2004). Such process is called trend stationary since the deviation from the trend stationary. However, most time series data have a characteristic of stochastic trend, i.e. the trend is variable, and cannot be predicted with certainty. In such cases, in order to avoid the problem associated with spurious regression, pretesting of the variables for the existence of unit roots becomes compulsory (Baltagi, 2008).

The reason for conducting stationarity test is due to the fact that if variables used in a regression are not stationary the results obtained using ordinary least squares (OLS) techniques would be incorrect. The standard assumption declares that when the sample size increases, sample covariances converge to population covariance- this shows consistence of the OLS estimator. However, the same pattern does not hold for non-stationary variables since they do not fluctuate around a constant mean (Verbeek, 2004).

Likewise a problem arises when two unrelated non stationary time series are regressed with each other. The results from these regressions are likely to be characterized by high R^2, unlikely auto correlated residuals and high regression coefficients in relation to their standard errors. Such results may be due to the fact that the variables share common trends (Ali, 2012).

To test for a unit root there are a number of tests with varying approaches have been developed. Among the methods of testing the presence of a unit root in a series the common ones include Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) and Phillips-Perron and KPSS. Based on the usual DF test, the series Y will be stationary and absolute value of θ in the equation is less than unity. However, it will not be stationary if the absolute value of θ in the above unit root is mainly conducted using Augmented Dickey-Fuller (ADF) test. The ADF test is a means of conducting a DF test in the presence of auto-correlated errors. The ADF is preferred to the DF test since it takes care of error autocorrelations by including lagged values which is not applicable in the Dickey-Fuller (DF) test. Thus, this paper employs ADF test for stationary test (Gujarati, 2004).

After estimating the model, decision is made using t-statistics. If the calculated t-statistic is less than the critical value from Dickey-Fuller distribution the null hypothesis will be rejected. Failing to reject the null hypothesis on the other hand implies the presence of unit root, i.e., and the series is non stationary.

3.3.2 Co Integration Tests

Differencing the variables to attain stationarity generates a model that does not show long run behavior of the variable, i.e. though they are individually non stationary, a linear combination of two or more time series variables can be stationary implying the presence of co integration and long run relationship among the non-stationary variables in the system. Thus, in order to obtain both the short-run and long-run relationship, applying co integration is mandatory. Co integration among the variables reflects the presence of the relationship in the system. Hence, testing for co integration is the same as testing for long-run relationship.

Among the approaches or methods of co-integration test the common one is carried out using the maximum likelihood estimator from the Johansen maximum likelihood procedure (Johansen, 1995). Unlike the Engle-Granger two step co-integration test, this method allows for testing the presence of more than one co-integrating vector and gives asymptotically estimates of the co-integrating vectors (the βs) and of the adjustment parameters (the α). Besides, it permits to estimate the model without restricting the variables as endogenous and exogenous The Johansen procedure enables estimating and testing a model for the presence of multiple co integration relationships, in a single-step procedure.

Under this procedure, the variables of the model are represented by a vector of potentially endogenous variables. In the (Johansen, 1995) procedure, determining the rank: provides the number of co integrating vector between the elements of an equation. To conduct a test for co-integration in a multivariate framework using Johansen's maximum likelihood procedure, first a general VAR (vector autoregressive) model has to be formulated. By considering k lags, a general VAR (k) model is formulated:

$$Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + \cdots + A_k Y_{t-k} + \mu + \emptyset D_t + \varepsilon_t$$

Where $Y_t = an$ n x 1 vector of stochastic I (1) variables.

A_i $(i = 1 \ldots k)$ is an n x n matrix of parameters.

μ is a vector of deterministic component (or a constant or trend).

D is a vector of dummies, intercepts & predetermined exogenous variables.

ε_t= a vector of normally & independently distributed disturbance terms.

The Johansen procedure follows five major steps in analyzing the co-integrating relationships. Similar to the Engle-Granger approach the first step is to test the stationarity of the variables under study. If all variables are found to be integrated at the same order then the co-integrating analysis continues without suffering from spurious regression (Johansen, 1995).

The second step in the Johansen's procedure is the selection of the optimal lag length. The optimal lag length selection is very important because the error terms do not suffer from non-normality, autocorrelation and heteroscedasticity problems. The Akaike Information Criteria (AIC) and Schwartz

Information Criteria (SIC) are frequently used to select the optimal lag length. This is mainly because they impose harsher penalty for adding more regressors than other lag length selection criteria. By estimating the VAR model from higher number of lags to lower (till it reaches zero) the model that minimizes the AIC or the SIC is selected as the one with the optimal lag length (Gujarati, 2004).

The third step is the identification of whether the constant term or trend enters the long-run and short-run models. The model selection procedure goes from the most restrictive model and stops when the first time the no co-integration is found by comparing the trace test statistic to its 5% critical value.

The fourth step is followed by determining the number of co-integrating vectors using two methods which both involve the estimation of matrix Π. The first method is based on the maximum Eigen-value statistic denoted byλ_{max}. This method tests the null hypothesis that the rank Π is equal to r against the alternative hypothesis$r + 1$. The null that is tested is that there are up to r co-integrating relationships and the alternative hypothesis is that there is $r + 1$ vectors. To test if the numbers of characteristic roots are significantly different from zero, the test uses:

$$J_{max} = \lambda_{max}(r, r + 1) = -Tln(1 - \hat{\lambda}_{r+1})$$

Where T is the sample size and λs are the characteristic roots.

The second method tests the trace of the matrix. The null hypothesis in this case is that r is equal to or greater than the number of the co-integrating relationships. The test checks whether the trace statistic increases as Eigen-value. The trace statistic is calculated as:

$$J_{trace} = \lambda_{trace}(r) = -T \sum_{i=r+1}^{n} \ln(1 - \hat{\lambda}_i)$$

After identifying the number of co-integrating vectors, the last step is the test for weak erogeneity. According to (Gujarati, 2004), weak exogenous test is defined as testing short-run feedbacks to deviations from the long-run relations.

3.3.3 Error Correcting Model

In light of the above discussion, two variables that are non-stationary in levels might have a stationary linear combination of series implies that the two variables are co-integrated. Accordingly, existence of co-integration allows for the analysis of the short run dynamic model that identifies adjustment to the long run equilibrium relationship through the error correction model (ECM) representation.

The model is as follows:

$$\Delta Y_t = \alpha + \sum_{i=1}^{k} \beta_1 \Delta y_{t-i} + \sum_{i=0}^{k} \theta \Delta X_{jt-i} + \delta ECT_{t-1}$$

Where Δy_{t-i} is the lagged first differences of the endogenous variable, X_{jt-i} is the current and lagged first differences of the explanatory variables and ECT_{t-1} is the error correcting term whose coefficient measures the speed at which prior deviations from equilibrium are corrected. Thus, the short run dynamic model is estimated using the Error Correcting Model specifications.

3.4 Model Specification

The efforts to measure the economic impact of climate change is growing. However, little research has focused specifically on the developing nations until the eve of 21st century (Mendelson, The Impact of Climate Change on Agriculture in Developing Countries, 2008).

Little is known about how climate change may affect the Kenya's agriculture and hence the economy. To assess the likely economic impacts of climate change, researchers have perused either partial equilibrium or general equilibrium approaches (Deressa, 2006).

This research paper adapted and employed the Solow and RCK growth models so as to determine the impact of climate change on economic growth- real GDP. They focus on output(Y), Capital (K), Labor (L), and Knowledge. It is believed that at any time, the economy has some amounts of capital (physical or human), labor/population, and knowledge, and these are combined to produce output. According to these scholars, the production function takes the form:

$$Y(t) = f(K(t), A(t)L(t)$$

However, natural resources, pollution and other environmental considerations such as macro variables of climate change-precipitation and temperature are absent from the Solow and RCK models. Such factors are seeing a being important in the estimation of long term growth.

An ever increasing output may generate an ever increasing stock of pollution that will bring growth to an end. Thus, it is vital to address issues of how environmental limitations affect long run growth (Romer, 1986). This can be done by incorporating the damage function in the Solow and/or RCK growth model. In this regard, it is useful to distinguish between environmental factors for which there are well-defined property rights and those for which there are not.

The existence of property rights for an environmental good has important implications. For instance, markets provide valuable signals concerning how the good should be used. It enables to use the good's price to obtain evidence about its importance in production. But, with environmental goods for which there are no property rights, the use of a good has externalities. Firms can pollute without compensating the people they harm. Thus, government's intervention is much stronger so as to solve the environmental problems such as climate change issues.

Declining quantities of resources and land per worker are not the only ways that environmental problems can limit growth. Production creates pollution, which reduces properly measured output: global warming could reduce output via its impact on weather patterns/climate change (Stern, 2006).

In the dynamic approach the growth model can be adapted or reshaped by incorporating the damage function for analyzing the impacts of climate change on economic growth- a country's GDP. The previous researchers in the area used panel data for their econometric analysis so as to identify the effects of cross-country variation in climate change variables on economic growth. For this study the researcher has employed time series data for the purpose of an econometric analysis. This is because climate change is a dynamic phenomenon that changes continually overtime. Thus, using time series data assures a contextual (meaningful) approach so as to deal with the impact of climate change on economic growth over a specified period of time. The proxy variable for economic growth is represented by $RGDP_t$ (Real GDP at a given time) whereas the proxy variables for climate change are represented by temperature and precipitation.

The model again takes this form:

$$Y_t = \beta_0 + \beta_1 POP_t + \beta_2 HC_t + \beta_3 TEMP_t + \beta_4 RF_t + \varepsilon_t$$

In logarithmic form, it can be written as:

$$lnY_t = \beta_0 + \beta_1 lnPOP_t + \beta_2 lnHC_t + \beta_3 lnTEMP_t + \beta_4 lnRF_t + \varepsilon_t$$

Where lnY_t = Growth rate real GDP

$lnPOP_t$ = population growth rate

$lnHC_t$ = growth rate of human capital

$lnTEMP_t$ = change in temperature

$lnRF_t$= change in rainfall

ε_t = stochastic error term

4. RESULTS AND DISCUSSION

By using the estimation methods described in chapter three, this part presents the econometric test results and outputs of the estimated model with the their interpretations. It comprises of the test results on the presence of unit roots, co-integration as well as the outputs of estimated long run and short run relations among the co-integrated variables under the series. All empirical estimations were carried out using STATA.

4.1 Unit Root Test Results

In order to investigate for stationarity, the Augmented Dickey Fuller (ADF) test was applied. Since the unit root tests are sensitive to the presence of deterministic trends, in ADF test approach there are three models. The general model which includes intercept and time trend is estimated first, followed by the restrictive models, i.e. with an intercept term and without intercept and trend term. The null hypothesis claims that the time series variable under investigation has a unit root or is a non-stationary process. The alternative hypothesis states that the series has no unit root or is a stationary process. The results for the estimations are presented in the Table 1.1. (Check Appendix A)

According to the ADF test of stationarity, all the variables under each series are found to be non-stationary. The null hypothesis of unit root is not rejected for all series at their levels. The test results of the series are rightly judged based on the comparison between test statistic (calculated value) and critical values at 1% and 5% significance level. If the test statistic exceeds critical value(s) in absolute terms, reject the null hypothesis where as if it is less than the critical value(s), we do not reject the null hypothesis. For rejecting or not rejecting the null hypothesis, we can also use the p-value, which lies between zero and a unit inclusively (i.e. $0 \leq p \leq 1$).

The p-value is a matter of convenience for us and formulated by taking into account the number of degrees of freedom and tells us at what level our coefficient is significant. In general, for rejection we expect the t-statistics are high and the p-values are low and vice-versa for not rejecting the null-hypothesis.

Since all the variables are non-stationary at their levels, a regression analysis using ordinary least squares (OLS) may produce spurious results. In order to solve this kind of regression problem, all the series should be differenced. After taking their first difference of I (l) variables, the OLS method can be used in regression analysis and estimation. However, there is also a problem with differencing: the possibility of losing long run information present in the variables. This problem can be solved by applying co-integration technique. This is because co-integration method considers the long run relationship among the non-stationary series.

4.2 Co-integration Analysis and The long run Model

Variables entering in the estimation equation are required to be stationary. Accordingly, unit root test is conducted using Augmented Dickey-Fuller (ADF) test. The unit root test indicated that all the variables are non-stationary at level, which indicates that presence of long-run relationship or co-integration should be cross-checked before conducing further econometric analysis. Given the possibility to have zero to k-1 linearly independent co-integrating relations for k endogenous variables, it is necessary to determine the number of co-integrating equations (rank of co-integration).

The existence of co-integration vector is tested using the Johansen Maximum Likelihood estimation method. However, in order to proceed with the application of Johansen co-integration test, the order of a VAR (Vector Autoregressive) model should first of all be identified. That means it requires determining the optimal number of lags to be included in the model at hand. There are various kinds of tests that can be used to choose appropriate lag length. Among them the Akaike information criteria (AIC), Final Prediction Error (FPE) criteria, the Bayesian information criteria (BIC) and the Hnnan-Quinn information criteria (HQIC) are the most widely used pre-conditions for lag selection. Based on these lag selection criteria, lag 2 is selected for the model under consideration. (Check Appendix B)

By using the selected optimal lag length for the model, the Johansen cointegration test is applied so as to identify the presence as well as the rank of cointegrating equations among the variables in the model. The test result of this procedure is displayed here under:

Table 1.2: Results of Johansen Co-integration Test

H_0	Log Likelihood	Eigen Value	Trace Statistic	5% Critical Value
0	320.3220	-	73.0441	68.52
1	333.9102	0.5723	45.8677*	47.21
2	345.2335	0.5072	23.2212	29.68
3	353.2046	0.3924	7.2790	15.41
4	356.7658	0.19955	0.1565	3.76
5	356.8401	0.0049	-	-

* indicates that this estimator has selected a single(r = 1) co-integrating equation (Johansen, 1995)

According to the above Johansen co-integration test, it has indicated the existence of one co-integrating equation in the model. As can be verified from Table 1.2, the null hypothesis of zero co-integrating equation against one or more cointegrating equations is rejected at 5% level of significance for the model. However, the null hypothesis of one against two or more co-integrating equations is failed to be rejected.

The presence of a single co-integrating vector points to estimate the long run equation along its associated coefficients (β) and the adjustment parameters (α) which plays a crucial role for further analysis.

Table 1.3: Normalized Long Run Model (Johansen Normalization)

Variables	Coefficients	Standard Error	p-value
LRGDP	1.0000	-	-
LPOP	0.4814	0.2496	0.001
LHC	-0.5349	0.4752	0.000
LTEMP	0.6325	0.8402	0.000
LRF	-0.5428	0.1824	0.003
Constant	-29.601	-	-

Table 1.4: The results of Short run Dynamic model

Dependent Variable: LD-LRGDP			
Variables	**Coefficients**	**Standard Error**	**p-value**
Constant	0.0160	0.5511	0.124
LD-LPOP	-0.5339	1.5009	0.188
LD-LHC	-0.0640	0.1507	0.006
LD-LTEMP	-0.5156	0.7725	0.505
LD-LRF	-0.1612	0.1755	0.358
ECT-1	-0.1612	0.2208	0.005
R^2 = 0.6548 **Adj R^2** = 0.6435 **DW**= 1.48 **F (4, 26)** = 8.962[0.000] **			

*LD - refers to lagged difference and *L- refers to logarithmic expression.

The adjustment coefficients (α's) obtained from the co-integration equation shows the speed of adjustment of the variables towards the steady state following a deviation from the pattern of long run equilibrium. The values of adjustment coefficients for the model under study, in table 1.4, indicate that differenced values of population growth rate has higher tendency to adjust itself to the long run equilibrium after certain shock has been imposed in the system followed by temperature and rainfall/precipitation respectively. The vector error correction model (VECM) captures both the long run and short run relationships among variables in the model. The change in the variables represent variation in the short run, while the coefficient obtained for the error correction term (ECT) represents the speed of adjustment towards the long run equilibrium. As we can see from Table 1.4, the lagged error correcting term (ECT-I) is significant at 5% level of significance. The coefficient this term indicates that 62.6% of the disequilibrium in the previous period is corrected in one year.

The overall fit of the model is acceptable as indicated by the goodness of fit of the model (R^2), which implies 65% of the variation in the dependent variable (lagged difference in log form of LRGDP) is explained by the variation in the explanatory variables included in the model). The F-statistic (test for joint significance) also rejected the null hypothesis that all the coefficients in the model are insignificant. The Lagrange-multiplier (LM) test confirmed that there is no autocorrelation problem. Similarly, the various diagnostic tests performed indicated that the errors in the estimated model are not correlated, are normally distributed and have constant variance. Furthermore, the Ramsey test (RT) for functional form misspecification also did not reject the regression specification of the dynamic model.

The Johansen co-integration test reported in the table 1.2, indicated that among the variables included in the model under study there is one co-integrating equation. According to this result, the single equation of the model with the estimates of the long-run coefficients can be written as:

$$LRGDP_t = 29.601 - 0.4814LPOP_t + 0.5349LHC_t - 0.6325LTEMP_t + 0.5428LRF_t$$

The p-values for each variable are as seen in table 1.3.

This equation represents the long-run equation or model for the impact of climate change on economic growth- real GDP. The joint statistic (F-test) can be conducted to identify statistically significant explanatory variables among those included in the model. From the equation, the p-value indicated that all the included explanatory variables have significant effect on economic growth proxied by real GDP. Besides, model diagnostic tests for serial correlation and normality of the residuals indicated that the estimated equation/model has no problem of serial correlation as well as non-normality as the null hypothesis for both tests failed to be rejected at the conventional significance levels. Furthermore, the heteroscedasticity test confirmed that the errors have constant variance. The results of the estimated model in which economic growth is proxied by the logarithm of RGDP and that of climate change proxied by the logarithm of temperature and rainfall are described as follows. According to this result, the impact of population growth and temperature are found to be negative and significant. On the other hand human capital and volume of rainfall have positive and significant contribution for the economic growth- real gross domestic product of (RGDP) a country over the study period.

The impact of climate change proxied variables on economic growth (RGDP) along with other variables on the right hand side (RHS) of an econometric equation can be interpreted by using the estimated coefficients as follows. Since the formulated econometric equation is in log-log form, the coefficients are interpreted as elasticity or responsiveness of change. An increase of 1% in population growth rate implies that the real GDP of a country is declined by 0.48% where as a 1% increment of human capital (adjusted for health, education, R & D) leads to an increment of real GDP by 0.53%. In the same vein, a 1 degree Celsius increase or change in temperature leads to a reduction of real GDP by 0.63% where as a 1mm increase or change in rainfall or precipitation pattern leads to an increase of real GDP by 0.54% respectively. The results clearly revealed that human capital has positive and significant impact on economic growth, which is in accordance with the theory that human development enhances economic growth. This is supported by numerous studies on the subject, including among other, (Romer, 1986).

Population growth and economic growth have a close relationship over periods; the arguments about positive and negative effects of population on economic growth are still complicated and opinions are diverse. (Acemoglu & Robinson, 2012) stated that the population growth can reduce the output per capita because population increases at a geometrical rate while production rises at an arithmetic rate so that output growth rate cannot keep the same pace. This supports the findings of this paper since population growth reduces economic growth- negative relationship.

Conversely, other famous early classical economists, Adam Smith and Marshal, argue in favor of positive effect of population growth. Both argue that a growing population widens market opportunities, foster creativity and innovation that eventually lead to higher productivity. But, this is true for developed countries. Thus, sign and effect of both population (in Less Developed Countries) growth and human capital are in line with the theoretical expectations and studies of scholars in the respective areas.

The Kenyan economy is climate sensitive since the agricultural sector depends on rainfall availability and an increase of temperature overtime retards economic growth- real GDP. Other studies support the findings of this paper: (Dell, Jones, & Olken, Temperature and Income: Reconciling New Cross-Sectional and Panel Estimates. , 2009) found that due to climate change (an increase in temperature), the growth rate of poor countries would be reduced by 0.6 to 2.9% points. Likewise in Zambia, 0.4% loss of growth occurred annually between 1977 and 2007 due to climate variability (James & Tingiju, 2009).

The above findings imply that regions or countries with strong dependence on agriculture would be affected much due to the anticipated changes in climate conditions. Thus, the impact of climate change is severe in developing countries like Kenya. Alongside the climate related problems, political economy and governance issues are key determinants to a country's growth and environmental quality.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This paper has examined the potential impacts of climate change on Kenyan economic growth- real GDP using a time series data (1980-2012). In doing so, an econometric model has been constructed based on theoretical and empirical literatures of the economics of climate change, then it has employed a growth model adapted from the Solow and/or RCK growth model. Accordingly, the result shows that an increase in temperature has a negative impact on economic growth measured by real gross domestic product. On the other hand, since Kenya depends on rain-fed agriculture which comprises a huge share of GDP, a decline in rain fall reduces an economic growth measured by real GDP. The reduction in economic growth will also result in increasing poverty. Thus, control of climate change is not only important for economic growth issue, but also crucial for poverty alleviation.

The result asserts that if climate change is not controlled, the economic growth will be reduced (an increase in temperature dangers a lot) considerably in the long run.

However, Kenya alone can do very little with regard to controlling climate change as its share of Green House Gas emissions in comparison to developed countries is small. Although the developing countries like Kenya contribute the least to causing climate change, they are the most affected by this phenomenon. This is due to their dependency on agriculture and their inability to pay for the resources necessary to combat climate change via adopting the preventive measures (mitigation) and adaptation techniques.

5.2 Recommendations and Policy Implications

Since Kenya is experiencing the effects of climate change, it requires an active step in managing or controlling climate-related problems. In order to solve this negative externality, the mitigation (ex-ante) and adaptation (ex-post) strategies should be in place. Besides the direct effects such as an increase in average temperature or a short run dynamics in rainfall patterns, climate change also presents the necessity and opportunity to change to a new, sustainable development model- a Climate-Resilient Green Economy (CRGE) Strategy to protect the country from the adverse effects of climate change and to build a green economy. Furthermore, Kenya should firmly continue with the bargaining and active participation on climate change agreements at global scale so as to be compensated for the risk of Green House Gases emitted from industrialized countries who take historical responsibility for emission.

In response to the severe impacts of climate change on economic growth some possible climate-related strategies or programs and policies should be implemented. Since climate change has already begun in our country, mitigation to reduce its damage should be applied primarily. Then, adaptation should be the second and best method to reduce the adverse impact of climate change since adjustment is an important tool for the long-run economic growth. In line with these programs, government should apply policies related to climate change with objectives to minimize the emissions of Green House Gases by using alternative energy sources such as geothermal energy, hydrothermal energy and solar energy. Furthermore, building a strong Green Economy should be part and parcel of all stakeholders and the general public. This building of Green Economy enables for sinking carbon and in the long-run it promotes carbon market.

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APPENDICES

APPENDIX A

Table 1.1: Unit Root Test Results

Variables	Specification	ADF Unit Root Test				Order of Integration
		Test Statistic	1% Critical Value	5% Critical Value	p-value	
$LRGDP$	With Constant	1.556	-3.709	-2.983	0.9977	1(1)
	With Constant and Trend	-0.866	-4.325	-3.576	0.9597	
	No Constant and Trend	-2.575	-2.650	-1.950		
$DLRGDP_t$	With Constant	-4.123	-3.716	-2.986	0.0009	1(1)
	With Constant and Trend	-5.631	-4.334	-3.580	0.0000	
	No Constant and Trend	-2.719	-2.652	-1.950		
LOP_t	With Constant	-0.402	-2.445	-1.692	0.3495	1(1)
	With Constant and Trend	0.562	-4.325	-3.576	0.9969	
	No Constant and Trend	-0.402	-3.675	-2.969		
$DLOP_t$	With Constant	-2.026	-2.449	-1.694	0.0065	1(1)
	With Constant and Trend	-4.861	-4.334	-3.580	0.0004	
	No Constant and Trend	-3.682	-2.972	-2.626		
LHC_t	With Constant	3.061	-3.709	-2.983	1.0000	1(1)
	With Constant and Trend	0.046	-4.325	-3.576	0.9947	
	No Constant and Trend	-1.950	-2.650	2.193		
$DLHC_t$	With Constant	-3.716	-2.986	-2.084	0.0025	1(1)
	With Constant and Trend	-3.580	-3.584	-4.334	0.0012	
	No Constant and Trend	-2.652	-1.950	-0.689		
$LTEMP_t$	With Constant	-1.471	-3.709	-2.983	0.5478	1(1)
	With Constant and Trend	-2.826	-4.325	-3.576	0.1875	
	No Constant and Trend	1.017	-2.650	-1.950		

$DLTEMP_t$	With Constant	-5.810	-3.716	-2.986	0.0000	1(1)
	With Constant and Trend	-5.721	-4.334	-3.580	0.0000	
	No Constant and Trend	-5.631	-2.652	-1.950		
LRF_t	With Constant	-2.986	-3.716	-3.699	0.4314	1(1)
	With Constant and Trend	-3.580	-4.334	-3.868	0.4562	
	No Constant and Trend	-1.950	-3.754	-2.652		
$DLRF_t$	With Constant	-3.699	-3.716	-2.986	0.0041	1(1)
	With Constant and Trend	-3.868	-4.334	-3.580	0.0034	
	No Constant and Trend	-3.754	-2.652	-1.950		

* D- refers to first difference and L- denotes log forms of each series.

APPENDIX B

Selection Order Criteria

Sample is between 1983 and 2012 with 30 observations

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	166.495	-	-	-	15e-11	-10.7663	-10.6916	-10.5328
1	334.186	335.38	25	0.000	1.1e-15	-20.2791	-19.8308	-18.8779
2	353.115	37.857	25	0.048	1.9e-15*	-19.8743*	-19.0525*	-17.3054*
3	353.115	56.856	25	0.000	2.4e-15	-20.1028	-10.9075	-16.3663

APPENDIX C

Lagranger-Multipler (LM) Test

Lag	**Chi^2**	**df**	**Prob> Chi^2**
1	19.0981	25	0.79239
2	23.2949	25	0.56035

$\boldsymbol{H_0}$: No autocorrelation at lag order.