

SCHOOL OF GRADUATE STUDIES

**THE IMPACT OF CLIMATE CHANGE ON ECONOMIC
GROWTH**

TIME SERIES EVIDENCE FROM ETHIOPIA

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SCHOOL OF GRADUATE STUDIES

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Table of Contents

Contents	Page
Abstract	I
Acknowledgment	II
List of Tables.....	III
Acronyms.....	IV
CHAPTER ONE: INTRODUCTION	
1.1. Background of the Study.....	1
1.2. Statement of the problem.....	6
1.3. Objectives of the Study.....	9
1.4. Significance of the study.....	10
1.5. Scope of the study.....	10
1.6. Limitation of the study.....	11
1.7. Organization of the paper.....	11
CHAPTER TWO: LITRATURE REVIEW	
2.1. Conceptual framework of climate change.....	12
2.2. International Response to Climate Change.....	19
2.3. Environmental conditions and implication of Climate Conventions for Ethiopia	22
2.4. Theoretical Reviews.....	24

2.5. Empirical Reviews.....	28
CHAPTER THREE: METHODOLOGY AND ECONOMETRIC ANALYSIS	
3.1. Data and sources.....	31
3.2. Time series conceptual framework.....	32
3.3. Method of Data analysis and Estimation techniques.....	35
3.3.1. Stationary and Unit root tests.....	35
3.3.2. Co integration test.....	38
3.3.3. Error Correcting Model.....	42
3.4. Model Specification.....	43
CHAPTER FOUR: RESULTS AND DISCUSSIONS	
4.1. Unit root test results.....	46
4.2. Co integration Analysis and the long run Model.....	48
CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS	
5.1. Conclusions.....	56
5.2. Recommendations and Policy implications.....	57
REFERENCES.....	58
APPENDICES.....	63

ABSTRACT

Climate change is one of the greatest environmental challenges facing the world today. It is recognized that climate Change and its associated extreme events will have a wide range of effects on the environment and socioeconomic sectors. Recent experiences of the nation have shown that Ethiopia is vulnerable to climate change. This study has attempted to investigate the impact of climate change on Ethiopian economic growth over a period 1980 to 2012 using vector autoregressive (VAR) approach for analysis. To do so it has employed the growth model adapted from Solow-RCK growth models by incorporating the possible proxy variables for climate change-economic growth and other relevant variables having better explanatory power in the model.

On the basis of unit root test result all the variables are found to be integrated of order one $I(1)$; and then the Johansen ML procedure have been employed to test for the presence and rank of co integration. Accordingly, the co-integration test indicated the presence of one co-integrating equation in the model. The empirical results show that climate change with a proxy variable of temperature has a significant and negative impact on economic growth proxied by real GDP. Conversely, climate change with a proxy variable of rain fall has a significant and positive impact on economic growth on average. Along with these proxy variables other explanatory variables incorporated in the model such as population and human capital having negative-significant and positive-significant impacts on economic growth respectively. Thus, in order to solve the severe impact of climate change with an increase in temperature, climate-related programs (mitigation and adaptation) and policies which reduce the emission of greenhouse gases via using alternative energy sources should be implemented.

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List of Tables

Tables	Pages
Table 2.1 List of the most vulnerable Countries to Climate Change.....	16
Table 4.2. Results of Johansen Co-integration Test	47
Table 4.3. Normalized Long-run model.....	48
Table 4.4. The Results of Short-run Dynamic model.....	48

Acronyms

ADF	Augmented Dickey Fuller
AERC	African Economic Research Consortium
AIC	Akaike Information Criteria
APF	Adaptation Policy Framework
CO ₂	Carbon dioxide
CGE	Computable General Equilibrium
CSA	Central Statistical Authority
CRGE	Climate Resilient Green Economy
ECM	Error Correction Mechanism
ECT	Error Correction Term
EEA	Ethiopian Economics Association
ENMA	Ethiopian National Meteorological Agency
GDP	Gross Domestic Product
GHG	Greenhouse Gas
HDI	Human Development Index
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter-Tropical Convergence Zone
LDCs	Least Developed Countries
LM	Lagrange Multiplier
MDGs	Millennium Development Goals
ML	Maximum Likelihood
MoARD	Ministry of Agriculture and Rural Development
MoFED	Ministry of Finance and Economic Development
NAPA	National Adaptation Program Action

NBE	National Bank of Ethiopia
NMA	National Meteorological Agency
NAMA	Nationally Appropriate Mitigation Action
OECD	Organization for Economic Cooperation and Development
OLS	Ordinary Least Squares
PIF	Policy and Investment Framework
PANE	Poverty Action Network of Civil Society
RT	Ramsey Test
RCK	Ramsey-Cass-Koopmans
SAM	Social Accounting Matrix
SSA	Sub-Saharan Africa
UNCED	United Nations Conference on Environment & development
UNDP	United Nations Development Program
UNEP	United Nations Environmental Program
UNFCCC	United Nations Framework Convention on Climate Change
VAR	Vector Autoregressive
VECM	Vector Error Correction Model
WCP	World Climate Programme
WMO	World Meteorological Organization

CHAPTER ONE

INTRODUCTION

1.1. Background of the study

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).

According to the Stern review (2006), the scientific evidence is now overwhelming and declaring that 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.

Climate change presents a unique challenge for economics: it causes the greatest and widest ranging market failure ever seen. The economic analysis must there be global, deal with long-time horizons, have the economics of risk and uncertainty at centre stage and examine the possibility of major, non-marginal change. Using the results from formal economic models, the review estimates that if we do not act, the over all costs and risks of climate change will be equivalent to losing 5% of global GDP each year, now and forever. Conversely, the costs of action-reducing greenhouse gas (GHG) emissions to avoid the worst impacts of climate

change - can be limited to around 1% of global GDP each year. This indicates that there is still time to avoid the worst impacts of climate change and, so prompt as well as strong action is clearly warranted. It must be based on shared vision of long-term goal and agreements on frameworks that will accelerate action should be on the basis of mutually reinforcing approaches at regional, national, and international level.

Ethiopia is one of the least developed countries (LDCs) in the world about 30% of its population living under the national poverty line (MoARD, 2010). Its human development index (HDI) is 0.414; ranking 171st out of 182 countries (UNDP, 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). Besides, development in the country is also challenged by several environmental problems (NMA, 2007; MoFED, 2007). The environmental problem such as climate change is a serious issue of this current century and needs to be dealt in a greater depth.

As in most developing countries, Ethiopian economy is dominated by agricultural sector which in turn can affect other sectors via its value chain system. However, the performance of the sector has been very weak (Dereesa and Hassan, 2010) due to 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 response to this climate change or dynamics, Ethiopia has recently established a national climate change forum and a civil society network on climate change, and has submitted both a national adaptation program of action (NAPA) and a nationally appropriate mitigation action (NAMA) plan to the United Nations framework convention on climate change (UNFCCC).

Climate change is one of the main problems affecting the global environment that is critical to human welfare. Climate change refers to a long-run increase in average surface temperature which goes under the name “global warming” or sometimes the “greenhouse effect”. It is caused by increases in greenhouse gases such as carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O), plus three fluorinated industrial gases: hydro fluorocarbons (HFCs), per fluorocarbons (PFCs), and sulphur hexafluoride (SF₆). Under normal (i.e., pre-industrial) conditions, greenhouse gases in the earth’s atmosphere serve to raise the temperature of the earth’s surface making it habitable. With no greenhouse gases at all, the surface of the earth would be about 30^oC cooler than it is today, making human life impossible. However, an increase in the greenhouse gas content of the earth’s atmosphere beyond the global balance leads to an increase in average global temperature.

Evidences indicate that the CO₂ 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^oC 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^oC between 1990 and 2100 (IPCC 2007). Carbon dioxide is the most significant one, accounting for 49% of global warming.

The principal reason for global warming is one and a half century of industrialization. These anthropogenic activities include the burning of ever-greater quantities of oil, gasoline, and coal, the cutting of forests, and the practice of certain farming methods. These activities have increased the amount of greenhouse gases in the atmosphere, especially carbon dioxide, methane, and nitrous oxide (Shah 2010; IPCC 2007). The modern communications media that inform us almost daily climatic catastrophes happened somewhere in the world

also bring news of the resulting property damage, crop failures, famine or deaths and aggregately economic growth (GDP) in our context.

A growing body of evidence suggests that abuse of the environment may enhance the likelihood of these climatic catastrophes. For this reason, climatology treats the role of humankind as well as the natural factors. It extends the findings of meteorology in space and in time to encompass the entire earth and periods of time as long as observations or scientific inference will permit. Since climatology involves the collection and interpretation of observed data, it necessitates instrumental and statistical techniques. The history of climate is concerned with changes through time. Time like space, is a continuum and its divisions are products of human imagination. Thus, time scales of climate commonly are based on the kinds of available evidence and theoretical explanations of change (Critchfield, 2003).

It is desirable that any study of the potential consequences of future climate change should use the best available information about projected climates. These projections are most commonly obtained from global climate model (GCM) simulations of the climate response to a given scenario of future GHG emissions into the atmosphere. Future emissions depend on human actions are inherently unpredictable. Besides, the effects of changing emissions on climate are not yet properly understood and can not be modeled with confidence. For these reasons, model projections of climate change are described as scenarios rather than projections (Carter *et al*, 2001). The earliest of the potential impacts of global warming in Europe were based on idealized equilibrium global climate model (GCM) simulations. Later climate scenarios were based on more transient CGM simulations. Recent studies have stressed the importance of capturing additional sources of uncertainty attributable to multi-decadal natural variability (Hulme, 1996). One feature of most of these scenario construction exercises was a focus



on particular time horizons in the future, often 30year periods, for which impacts were estimated and compared to impacts during a baseline period.

Climate as a summation of all atmospheric events over an infinite time span does not change. That means climate change has no meaning unless we establish a time scale for comparing specific periods and analyzing trends. Averages for an arbitrary number of years (commonly 10 to 30 years) facilitate studies of trends. The monthly means of temperature and precipitation for three successive decades are taken as climatic normal for comparisons. Much empirical research on climate change has tended to emphasize one climatic element, usually temperature or precipitation, whose values can be graphed as a function of time. Magnitude and sequence of climatic events are fundamental in all studies of climatic change, but chronology is equally essential for correlating different kinds of proxy evidence and for making worldwide comparisons. Several kinds of proxy data combine climatic data with a parallel chronology (Critchfield, 2003).

The impacts of climate change are not evenly distributed - the poorest countries and people will suffer earliest and most. Such change will have a disproportional negative impact on developing countries (IPCC, 2007). If the damages appear, it will be too late to reverse the process. Thus, we are forced to link a long way ahead. Climate change will aggravate problems related to rapid population growth, existing poverty and a heavy reliance on agriculture and the environment. Developing countries have a limited capacity to cope with the problems caused by climate change. In this regard climate change is a serious threat to the developing world and a major obstacle to continued poverty reduction across its many dimensions. First, developing regions are at a geographic disadvantage-they are already warmer than developed regions, and they also suffer from high rainfall variability. As a result, further warming will bring poor countries high costs and few benefits. Second, developing countries are heavily dependent on agriculture,

the most climate sensitive of all economic sectors. Third, their low incomes and vulnerabilities make adaptation to climate change are particularly difficult.

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 effects of climate change (Stern, 2006; Tol, 2002). The climate change impacts first the physical geography, then it affects the human geography, which depends on when and what to do based on location. Besides, the high concentration of greenhouse gas will lead to further warming over the next few decades because of the inertia of climate system. For instance, an increase of CO₂ is thought to produce slightly higher surface temperature and it has been produced as a cause of the warming trend. A doubling of atmospheric CO₂ could raise surface temperature by 2C⁰ (Critchfield, 2003) 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. Statement of the problem

Climate change is one of the main problems affecting the global environment which is critical to human welfare. 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 cope, rampant poverty and most of them are located in regions where severe weather will hit the most. This makes it difficult to deal with the problem of climate change via unilateral efforts or even efforts of a certain group of countries can not solve it unless the world acts globally. This is because climate change is a universal or global issue. Given its massive and disproportional effect, the issue of climate change is no longer “things of the future” in Africa in general and

Ethiopia in particular. Human beings are likely to face climate change directly or indirectly and their welfare is negatively affected. The problem of global warming via GHG effect is complicated as it involves the entire world and it has no geographical demarcation (IPCC, 2007).

Industrialized countries contributed to 80% of the total atmospheric CO₂ building and their share of annual CO₂ emissions is 60% (Saha, 2010). This implies that though the LDCs like Ethiopia 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 Africa since the African 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 20th 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 (NMA, 2007).

Cline (2007) predicted that global agricultural productivity will be reduced by 15.9% by the 2080s under the customary warming rate, while 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, Ethiopia is thus not an exception and it is expected to carry

the burden of climate change effects. Besides, the impact may be worsen 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 Sub Saharan Africa (SSA) being central tool towards economic growth and most economic activities are dependent on agricultural expansion. In most of Africa about 80% of people are employed in the agricultural sector, one of the driving forces of the economy, with GDP contribution of 30% to 60 % (Egnonto and Madou, 2008).

Likewise the importance of this sector is undeniable in the Ethiopian economy given that it is contributing about 43% to the country's GDP, generating about 90% of export revenues (MoARD, 2010), and supplying more than 70% of raw materials for agro-based domestic industries (Deressa, 2006; MoFED, 2007). As a result, any shock related to climate change on this sector would have wider economic impact on other sectors via 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.

1.3. Objectives of the study

Given the importance of agriculture in Ethiopia, loss of its productivity due to climate change will affect the entire economy- real GDP. The prospect of climate change dictates the way economic activities will be practiced and provides a signal for the adjustment of existing climate change related programs-mitigation and adaptation-and climate change polices at macro level.

The general objective of this research paper is to assess the impact of climate change on the Ethiopian economic growth at macro level and provide some policy options following the findings for the achievement of societal well-being/ welfare.

The specific objectives of this study include:

- To quantify the impact of climate variables on economic growth-measured by a country's real gross domestic product.
- To identify the relationship between temperature and GDP as well as the relationship between rainfall and GDP.
- To suggest policy options which enable to manage or control climate-related impacts on economic growth at country level.

1.4. Significance of the study

In addition to its global nature, it is now widely recognized that climate change will have a large scale effect on economic outcomes. As a result, studying the economic impacts of climate change will help the country formulate effective policies, take adequate mitigation and adaptation actions and ensure active participation on global climate change agreements. Specifically, the study on climate change may contribute to the existing perception on the trends and impacts of climate change on economic growth and it will provide some policy recommendations that would help in designing the right policy related to climate change so as to reduce the negative impact of climate variability on Ethiopian economic growth at national level. The research effort and previous literature on the impact of climate change-economic growth relationship was based on cross country or panel data and specific crop productivity. However, this study follows time series approach providing some insights about impact of climate change on economic growth when a single country is considered. Thus, this study will be used as a ground for further country specific analysis of climate change-economic growth relationships.

1.5. Scope of the Study

While climate change is global in nature, potential changes are not expected to be globally uniform; rather, there may be dramatic regional differences. The key impacts of climate change are associated with the climate-related parameters of sea level rise, changes in the intensity, timing and spatial distribution of precipitation, changes in temperature (variations and mean values), and the frequency, intensity and duration of extreme climate events. Climate change is considered as mother of all externalities affecting social, economic and political affairs of a region or country. However, the scope of this paper is limited to the

analysis of economic impact of climate change on growth- measured by real GDP. To deal with the economic impact of climate change, the study covers the period from 1980 -2012 with the findings and conclusions applicable to Ethiopia and low income countries with similar features.

1.6. Limitation of the study

Although this study attempts to investigate the impact of climate change on economic growth, it suffers from some limitations. One of such limitations is that the study does not include all the possible explanatory variables which are expected to affect a country's economic growth. This is in order to avoid statistical complications which could be faced while using large number of variables with limited time period. The other limitation is regarding the time span considered; which might be short for time series analysis. These limitations happened from lacking of consistency and unavailability of the data.

1.7. Organization of the paper

This paper is organized with five chapters. Following the introductory chapter, the second chapter comes, which provides a review of related literature about the impact of climate change on economic growth -theoretically and empirically. The third chapter describes the methodological and econometric analyses. For the analysis, the Johansen Maximum Likelihood estimation procedure is employed using data for 1980 to 2012. Chapter four focuses on results and discussion. The last Chapter provides the conclusion and policy recommendations so as to solve problems related .to climate change.

CHAPTER TWO

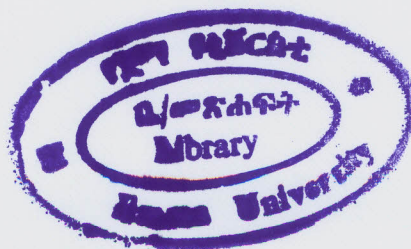
LITERATURE REVIEW

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 climates (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 (Ibid, 2003).

Climate, which we live in, affects every one 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 *et al.*, 2012). So, 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 (Christensen and 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 build up of greenhouse gases will cause the earth to warm (IPCC 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 (IPCC 2007; 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 is 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, 0.4percent loss of growth occurred annually b/n 1977 and 2007 due to

climate variability, and the accumulated cost for this period was US\$13.8 billion (James *et al*, 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 and Others (2006), in the next fifty years world temperature is expected to raise 2-3°C⁰. 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 *et al* (2008) 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 and 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, where as 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 *et al*, 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; 2005) 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 GHG emissions and lead to higher economic growth. Besides, Tol (2009) has argued that GHG 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 and 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 (Magnani, 2000). 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.

In 2010, Maplecroft released a climate change vulnerability index out of 170 countries, 16 countries were identified to be in a condition of extreme risk. The table below provides a list of the vulnerable countries arranged in their respective order of vulnerability to climate change.

Bangladesh(1)	Mozambique(5)	Zimbabwe(9)
India(2); Haiti(7)	Philippines(6)	Madagascar(3)
Vietnam(13)	Nepal(4)	Ethiopia(11)
Thailand(14)	Afghanistan(8)	Cambodia(12)
Pakistan(16)	Myanmar(10)	Malawi(15)

Table 2.1:- List of the most vulnerable countries to climate change
 Note that value in the brackets indicates the respective rank of the country to vulnerability. It is worth mentioning here that the variation in climate and geographic features in Ethiopia is among the vulnerable countries to climate change. Such climate change is resulting in the degradation of land, ecosystems, water and air quality. It is further threatening to undermine food security as well as causing health problems and impacting aggregate economic value real GDP.

Concepts and operational definitions that are relevant in climate change issues are the following, which are adapted from the Intergovernmental Panel on Climate Change (IPCC, 2007) and Adaptation Policy Framework (APF, 2005):

Weather - is the instantaneous state of the atmosphere and it is what we experience from day to day.

Climate - refers to the statistical averages of weather elements prevailing over a given place during a long period of time.

Climate variability- is a fluctuation of climatic parameters from the normal or base line values.

Climate change - is a change in the long-term mean value of a particular climatic parameter. It is a persistent long-term change.

Vulnerability - is the degree to which an exposure unit is susceptible to harm or climate change due to lack of ability to cope, recover or fundamentally adapt to it.

Resilience-is the amount of change a system can under go without changing state.

Coping range - is the range of climate where the outcomes are beneficial or negative but tolerable; thus, beyond this scope the damages or loss are no longer tolerable and the society or system is said to be vulnerable.

Climate-related risk- is the interaction of physically defined hazards with the properties of the exposed system. It can also be considered as the combination of an event, its likelihood, and consequences. Mathematically risk equals the probability of climate hazard multiplied by a given system's vulnerability.

Mitigation - is one of the strategies that countries need to take under the climate change convention. It involves reducing greenhouse gases (GHGs) to meet the objective of the UNFCCC (article 2).

Adaptation - is one of strategies under the convention, which is recognized as a critical response to the impacts of climate change, because current agreements to limit emissions even if implemented will not stabilize atmospheric concentrations of GHGs and climate change. It can reduce present and future losses from climate variability and change. It is neither a one-off intervention nor a stand-alone activity; rather it is a process that needs to be incorporated in the overall development planning, including the design and implementation of projects and programs across the relevant sectors.

2.2. International Response to Climate Change

Increasing awareness by international organizations and nation-states of changes in the ecosystems and the destruction of natural resources initiated the attempts to address environmental concerns on a global scale. The 1972 United Nations Conference on Human-Environment resulted in the establishment of the United Nations Environment Programme(UNEP). While the purpose of establishing UNEP was environmental assessment and research and monitoring, it also played a role in placing the link between environment and development on the international agenda. The First World Climate Conference was held on in 1979 in Geneva as one of the first major international meetings on climate change. It focused on climate change in addition to climate research and forecasting (UNFCCC, 2010).

The First World Climate Conference recognized climate change as a serious problem. This scientific conference explored how climate change might affect human activities and issued a declaration calling on the world's governments "to foresee and prevent potential man-made changes in climate that might be adverse to the well-being of humanity". It also endorsed the establishment of the World Climate Programme (WCP) under the joint responsibility of the World Meteorological Organization (WMO), the UNEP, and the International Council of Scientific Unions(ICSU). A number of international conferences were held in the late 1980s and early 1990s. Together with increasing evidences they helped to raise international concern about the issue of climate change. The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the UNEP and the WMO with the mandate to assess the state of existing knowledge about the climate system and climate change. They outlined environmental, economic and social impacts of climate change, and the possible response strategies.

In 1990 the IPCC issued its First Assessment Report, confirming that human-induced climate change was indeed a threat and calling for a global treaty to address the problem. The UN General Assembly responded to these calls in December 1990, formally launching negotiations on a framework convention on climate change by its resolution 45/212. These negotiations were conducted by an Intergovernmental Negotiating Committee (INC), chaired by Jean Ripert (France). Negotiators from 150 countries finalized the convention in 15 months and adopted by consensus the United Nations Framework Convention on Climate Change (UNFCCC) in New York on May 9, 1992. The UNFCCC was signed by 154 states (plus the European Commission, EC) at the UN Conference on Environment and Development (UNCED), otherwise known as the "Earth Summit", held 3–14 June 1992 in Rio de Janeiro. The Earth Summit became the largest ever gathering of Heads of States. Other agreements adopted at Rio were called the Rio Declaration- Biological Diversity and Forest Principles.

The UNFCCC is an international environmental treaty and sets an ultimate objective of stabilizing atmospheric concentrations of GHGs at levels that would prevent "dangerous" human interference with the climate system. To achieve this objective, all parties to the convention are subject to an important set of general commitments, which place a fundamental obligation on them to respond to climate change. However, the UNFCCC did not commit states to a specific and binding limitation on GHG emissions because of the sharp disagreements among the big emitters of carbon dioxide, especially the Organization for Economic Cooperation and Development(OECD) countries. Countries with large reserves and a dependence on oil, such as the United States, resisted the inclusion in the Convention of a timetable and a target for the reduction of CO₂ emission, which western European countries, with small relative

dependence on coal, favored. The Convention, however, established a mechanism for future action to be taken as warranted by scientific evidence.

The conference of parties (COP), held in Kyoto, Japan, on December 1997, adopted the Kyoto Protocol. The Kyoto Protocol is a legally binding agreement under which industrialized countries are committed to reduce their collective emissions of six GHGs by 5.2% from 2008–2012, calculated as average over these five years. It was also agreed that developing country parties would not be required to take on new commitments under these new processes. Agreements on the 5.2% targets and other issues, including the base year, were reached after tense negotiations, each country proposing different indicators as the basis for emission cuts. The only common theme of these indicators was that each proposal suited the interests of the country making the proposal. The complexity of the negotiations, however, meant that considerable “unfinished business” remained even after the Protocol was adopted. At the time of its adoption, the Kyoto Protocol sketched out the basic features of its “mechanisms” and compliance system, but did not develop all important rules on how they would operate.

The Kyoto protocol is praised by some as the first to impose legally binding commitments and emission reduction targets, strongly sought by those who argue that the international community must take immediate steps to stem the rise in global warming (Albert, 2001). However, the negotiations leading to the adoption of the Protocol reflected different interests of those parties with most to gain from their inclusion (Grubb 2003). Developed countries such as the United States and Australia pushed for the inclusion of carbon sinks (e.g., by including forests that absorb CO₂ from the atmosphere) in the protocol to minimize domestic political difficulties.

The UNFCCC provides for the periodic review of the emission reduction commitments. It was initially suggested in the Kyoto Protocol that negotiations for the post-2012 period would start in 2005. However, the long time it took to have the Protocol ratified meant that this negotiation had to start much later. Post-Kyoto negotiations refer to high level talks attempting to address global warming by limiting greenhouse gas emissions. Generally part of the UNFCCC, these talks concern the period after the first "commitment period" of the Kyoto Protocol.

2.3. Environmental conditions and implication of Climate

Conventions for Ethiopia

Environmental problem is now among the major problems which can have significant ecological, social and economic impacts in Ethiopia. The country's low growth rate of GDP, in one way or another, is linked to the changes in its natural and environmental conditions. As a result, it has been widely acknowledged recently that addressing such problems does have several important economic dimensions in line with millennium development goals (MDGs). Hence, it has become a key issue in the development agenda of the nation (MoFED, 2010).

Even though the deterioration of the natural environment due to unchecked human activities and poverty has further worsened the situation, the causes of most of the disasters in the country are climate related (NMA, 2007). Climate in Ethiopia is highly controlled by the seasonal migration of the Inter-tropical Convergence Zone (ITCZ), which follows the position of the sun relative to the earth and the associated atmospheric circulation. Furthermore, it is also highly influenced by the country's complex topography (NMSA, 2001).

As discussed, the impacts of climate change on Africa in general and Ethiopia in particular is not the thing of tomorrow; they are issues of today. Climate change is affecting them already and the impacts are predicted to be more severe in the future. This is consistent with the predictions of the impacts of GHGs on climate, which generally predicts that dry regions will be drier and wet regions become wetter (UNDP, 2006). As Sub-Saharan Africa and Ethiopia in particular are generally dry, they have been more vulnerable to the impacts of climate change than any other region. But given what is achieved today, the ambiguity of the second commitment period of the Kyoto Protocol and the uncertainty of the future outcomes of the impacts of climate change make them feel pressed between two hard rocks. The question of mitigation is no remedy for what is happening already. Ethiopia needs financing to cope with the current climate-related problems. At the same time reducing GHG emissions is needed to stop the worsening of climate change while adaptation is needed to cope with its future impacts.

While the Convention recognizes historical responsibility, those that are historically and currently responsible for climate change are reluctant to implement the commitments as agreed and GHGs continue to rise. The UNDP report calls the international response to climate change “unhappily” inadequate because of the lack of investment by nations in adaptation projects. As matters stand now, the prospect of stabilizing the concentration of GHGs below the “dangerous” level is not promising. The main problem is that climate change represents the worst form of negative externality that bears difficulty to make the polluters accountable for the external costs.

Yet the largest emitters of GHGs are either reluctant to act according to their commitments or do not want to commit themselves to quantified GHG reduction targets. It appears the reason that although climate change will

potentially impact both the largest emitters and those least responsible, the biggest emitters fear that their losses will be shouldered sooner than later. Unfortunately, the regional variation of climate change made Ethiopia more vulnerable to the impacts climate change.

2.4. 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 CO₂ concentration are some of the variables which can considerably affect agricultural development (Zhai and Zhuang, 2009).

According to 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, IPCC 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 owing 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 Ethiopia, 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 (PANE, 2009). In Ethiopia, 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, 2006).

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 (IPCC, 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, 2006).

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, 1991; Cline, 1994; Tol, 1995). 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 sectoral 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. The Mankiew, Romer and Weil (1992) model is also applied, but to a lesser extent. 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.

Theoretical Model:- Dell, Jones and Olken(2008) 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 production or growth function:

$$Y_{it} = e^{\alpha T_{it}} A_{it} L_{it} K_{it} \dots\dots\dots (1)$$

$$\Delta A_{it}/A_{it} = g_i + \beta T_{it} \dots\dots\dots (2)$$

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=1,...,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 where as 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:

$$g_{it} = g_i + (\alpha + \beta)T_{it} - T_{it-1} \dots\dots\dots (3)$$

Where g_{it} is 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.

2.4. 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 (Pearce *et al.*, 1996).

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 (Mendelsohn *et al.* 2006).

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 3c⁰ over the period 1990-2050, with various effects of climate change (Nordhaus, 1992). 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(1991) 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, he finds that drastic measures to combat global warming such as policies that would largely halt or end further warming by cutting emissions of GHGs by 50 percent or more would be much more harmful than simply doing nothing.

Using a similar approach, Nordhaus (1992) 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:

$$Y_t = \beta_0 + \beta_1 \text{POP}_t + \beta_2 \text{HC}_t + \beta_3 \text{TEMP}_t + \beta_4 \text{RF}_t + \varepsilon_t \dots\dots\dots (4)$$

Where Y 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, GHG emission levels, atmospheric GHG 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.

Although some empirical studies on climate change impacts in Ethiopia already exist (Deressa, 2007; Hssen and Ringler, 2008), they face some limitations. They focused their intention on specific crop productivity across agro ecological zones as a function of seasonal variation on climatic variables. Besides, the previous studies on Ethiopia have not tried to link the climate change issue to the broader context of economic growth –real GDP. As such they have not looked at climate change impacts in relation to economic growth at aggregate level(RGDP), which is what the present paper attempts to address

CHAPTER THREE

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 about 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.

Accordingly, the first category includes National Bank of Ethiopia (NBE), Central Statistical Authority (CSA) of Ethiopia, National Meteorological Agency (NMA) of Ethiopia, Ministry of Finance and Economic Development (MoFED), National Bank of Ethiopia (NBE) and Ethiopian Economics Association (EEA) data base (2012). And the online data sources include United Nations Development Program (UNDP), World Bank (WB) and Organization for Economic Cooperation and Development (OECD).

The complexity of climate-economy relationship is apparent. However, less discussed perhaps critical issue, the ideas or economic philosophy related to development that link productivity to temperature is vital. This paper takes a different approach rather than identifying mechanisms one-by-one and summing-up, it 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

For longtime there has been very little communication between econometricians and time series analysts. Econometricians have emphasized economic theory and a study of contemporaneous relationships. Lagged variables were introduced but not in any systematic way, and no serious attempts were made to study the temporal structure of the data. Theories were imposed on the data even when the temporal structure of the data was not in conformity with the theories.

The time series analysts, on the other hand, did not believe in economic theories and thought that they were better off allowing the data to determine the model. Since the mid-1970s the two approaches - the time series approach and the econometric approach - have been converging. Econometricians now use some of the basic elements of time series analysis in checking the specification of the econometric models and some economic theories have influenced the direction of time series work (Maddala, 1992).

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 fore ward, 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.

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.

Many of the intensive and sophisticated applications of time series methods have been available to problems in the physical and environmental sciences. More 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.

It is argued that an acceptable "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. Interest in the statistical nature of climate change has heightened in recent years. Just as the need for a paradigm to monitor climate change has been recognized (Wood, 1990), a model that defines climate change in statistical terms is required.

According to Maddala (1992), 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. We thus write X_t as:

$$X_t = \mu + \sum_j^a (Y_j \cos 2\pi f_j t + Z_j \sin 2\pi f_j t) \dots\dots\dots (5)$$

Where Y 's and Z 's are uncorrelated random variables with zero expectations and variances $\sigma^2 (f_j)$, and summation is over all frequencies f_1, f_2, f_3, \dots , are equally spaced and separated by a small interval Δf . The purpose of such analysis is to see how the variance of X_t is distributed among oscillations of various frequencies. The technique of analysis is called spectral analysis.

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.

In scenario, we begin with linear regressions of the present value of a time series on its own past values and on the past values of the other series. This kind of modeling leads to use the results of the time domain approach 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 test

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. A given variable (a stochastic process) is said to be stationary if it has a constant mean, constant variance over time and if the covariance between observations in two time periods depends on the distance of the lag between the two periods, (Gujarati, 2004). However, most macro economic variables are not-stationary variables that will often lead to a problem of spurious regression. Thus, it is necessary to test for stationary 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.

In time series analysis we do not confine ourselves to the analysis of stationary time series. In fact, most of the macroeconomic time series we encounter are nonstationary. Accordingly, time series can be classified as stationary and nonstationary. When we refer to stationary time series, we mean covariance stationary. A time series process X_t is said to be covariance stationary if its mean and variance are constant and independent of time and the co variances depend

only upon the distance between the two time periods, but not the time periods per se overtime.

A time series, y_t , is weakly stationary if the mean and variance are the same for all $t=1, 2 \dots T$, and if the auto covariance, $\gamma_s = \text{Cov}(y_t, y_{t-s})$, depends on s but not on t , where s subscripts individual observation and t proxies time (Nielson, 2007). If a time series failed to have the above properties then it is a non-stationary process. In other words, a non-stationary time series will have a time varying mean or variance or a time varying of both (Gujarati, 2004).

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. 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 can not 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.

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 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. This phenomenon is known as nonsense or spurious regression, as the results have no economic meaning (Granger and Newbold, 1974). Consequently, the conventional t and F tests would tend reject the hypothesis of no relationship when, in fact, there might be none (Verbeek, 2004).

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 regress this paper 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 selected than the DF test since it takes care of error autocorrelations by including lagged values which is not applicable in dickey-fuller(DF) test. Thus, this paper employs ADF test for stationary test.

The number of unit roots a given variable posses determines how many times that variable should be differenced in order to attain stationarity. In this regard, the DF test will enable to assess the existence of stationarity. However, the DF test may have a series limitation in that it suffers from residual autocorrelation. To amend this weakness, the ADF model will be augmented with additional lagged first differences of the dependent variable. This is called Augmented Dickey-Fuller, ADF test. This regression model avoids autocorrelation among the residuals.

Thus, incorporating lagged first differences of the dependent term in DF equation gives the corresponding ADF models.

The ADF unit root test requires the estimation of the following regression model:

$$\Delta y_t = \alpha + \beta y_{t-1} + \delta T + \lambda_1 \Delta y_{t-1} + \lambda_2 \Delta y_{t-2} + \dots + \lambda_k \Delta y_{t-k} + \varepsilon_t \quad \dots \dots \dots \quad (6)$$

Where α is intercept term, δ is trend coefficient, T is time or trend variable, ε_t is pure white noise error term and k is the number of lags specified. This is general form of the ADF regression as is incorporated the time trend(T) as well as an intercept /drift (α) which enables to check if the variable have deterministic trend and whether the true value of y_t is zero or not respectively.

The null hypothesis is that the variable contains a unit root, and the alternative is the variable was generated by a stationary process.

$$H_0: \beta = 0$$

$$H_1: \beta < 0$$

After estimating the above model decision is made using t-statistics. If the calculated t-statistic is less than the critical value from Dikey-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 test

Most macro economic variables are found to be non-stationary and hypothesis testing based on such variables is invalid. One of the mechanisms to attain stationarity is differencing and the number of unit roots a given variable posses determines how many times the variables should be differenced in order to make stationary (Gujarati, 2004). That means one can difference or de trend the

variables in a series so as to make them stationary. However, 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.

A stochastic process is said to be integrated of order p : $I(p)$, if it requires to be differenced p times in order to achieve stationarity. In general x_t and y_t are said to be integrated of order $CI(d,p)$ if both x_t and y_t are integrated of order d ; but there exist an α such that $y_t - \alpha x_t$ is integrated of order $d-p$. A vector of $I(1)$ variables y_t is said to be co integrated if there exist a vector β_i such that $\beta_i y_t$ is trend stationary. If there exist r such linearly independent vectors β_i , $i = 1 \dots r$, then y_t is said to be co integrated with co integrating rank of r and the matrix $\beta = (\beta_1 \dots \beta_r)$ is called the co integrating matrix.

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. 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 β 's) and of the adjustment parameters (the α 's). 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 (1988) 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:

$$Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + \dots + A_k Y_{t-k} + \mu + \phi D_t + \varepsilon_t \quad \dots \dots \dots (7)$$

Where $Y_t = an \ n \times 1$ vector of stochastic I(1) variables;

$A_i (i = 1 \dots k)$ is $n \times n$ matrix of parameters

$\mu =$ is a vector of deterministic component (or a constant or trend)

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

$\varepsilon_t =$ a vector of normally & independently distributed disturbance terms

Even though the co-integrating relations are present in a system of variables, as noted by Engle and Granger (1987), the VAR form is not the most continent model setup. In such case it requires to consider specific parameterizations that support the analysis of the co-integration structure. The model that can capture such relations between and among variables in a model is called vector error correction model (VECM) or vector equilibrium correction model. By subtracting Y_{t-1} from both sides in equation(7) and rearranging terms the VECM can be formulated as follows:

$$\Delta Y_t = \Pi Y_{t-1} + \Delta \Gamma_1 Y_{t-1} + \Gamma_2 \Delta Y_{t-2} + \dots + \Gamma_{k-1} \Delta Y_{t-k+1} + \mu + \phi D_t + \varepsilon_t \quad \dots \dots \dots (8)$$

Where $\Pi = -(I - \sum A_i)$

$\Gamma_i = -(I - \sum A_j) \dots \dots \dots$ with $i = 1, 2, \dots, k-1$ and I an identity matrix.

The long run relation among the variables is captured by the term ΠY_{t-1} and the Γ_i coefficients estimate the short run effects of shocks on ΔY_t . According to the Johansen (1988) procedure, determining the rank of Π (i.e. the maximum number of linearly independent stationary columns in Π) provides the number of co-integrating vector between the elements in y . In line with this proposition, the following three cases should be identified:

- a. If the rank of $\Pi = 0$, it declares that the matrix is null in which the variables are not cointegrated. In such circumstances the VAR model is used in first difference, with no long run information.
- b. If the rank of Π equals the number of variables in the system ($n=r$), then Π has full rank which implies that vector process is stationary. Therefore, the VAR can be tested in levels.
- c. If Π has a reduced rank: $1 \leq r(\Pi) \leq n$, then it suggests that there exists $r < (n-1)$ cointegrating vector where r is the number of co-integrating equations in the system.

The matrix Π is given by the formula: $\Pi = \alpha\beta'$ where α (adjustment parameters) and β (co-integration parameters) are $n \times r$ matrices, representing the speed of adjustment to the long run equilibrium after certain shocks and the long run relationship between the variables in the system, respectively. In order to determine the number of co-integrating vectors, the Johansen procedure provides n eigen values (λ characteristic roots) whose magnitude measures the degree of correlation of co-integration relations with the stationary elements in the model.

There are two test statistics that are used to test the number of co-integrating vectors based on the characteristic roots: λ -trace and λ -max. The formulae used for calculating the statistics are:

$$\lambda_{\text{trace}(r)} = -T \log \sum (1 - \lambda_i^T), \quad r = 0, 1, 2, \dots, n-1 \quad \dots \dots \dots (9)$$

$$\lambda_{\text{max}} = -T \log (1 - \lambda_{r+1}^T) \quad \dots \dots \dots (10)$$

Where λ_i = estimated value of characteristic roots(eigen values) from Π matrix

T = is the sample size or the number of usable observations

λ -trace tests the null that the number of co-integrating vectors is less than or equal to r against an alternative of $(r + 1)$. On the other hand, λ -max statistics tests the null that the number of co-integrating vectors is r against an alternative of $(r+1)$. The distribution of both test statistics follows Chi-square distribution.

3.3.3. The Error Correcting Model (ECM)

In light of the above discussion, two variables that are non-stationary in levels might have a stationary linear combination of series implying 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. Given the co-integrating rank of the series, the error correction model (ECM) can be formulated as follows:

$$\Delta Y_t = \alpha + \sum_{i=1}^k \beta_i \Delta Y_{t-i} + \sum_{i=0}^k \theta_i \Delta X_{jt-i} + \delta ECT_{t-1} \quad \dots \dots \dots (11)$$

Where ΔY_{t-i} is the lagged first differences of the endogenous variable, ΔX_{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 ECM specifications.

In the following section, the results of econometric tests and estimations are presented. In order to estimate the time series data and present the output, appropriate soft ware packages should be used. Accordingly, in this paper all the empirical estimations are conducted by using the econometric soft ware package called STATA 11 version.

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 (Mendelssohn and Dinar, 1999). Although more studies dedicated to developing countries have emerged since then, a few national level studies for Ethiopia have been done. Accordingly, little is known about how climate change may affect the country'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 and Hassan, 2009).

Partial equilibrium models are based on the analysis of part of the overall economy such as a single market or subsets of markets or sectors - assuming no interrelationship among sectors. However, general equilibrium models are analytical models, which look at the economy as a complete, interdependent system, thereby providing an economy wide prospective analysis capturing links between all sectors of the economy (Zhai *et al.*, 2009). But, the impacts of climate change are analyzed by emphasizing only one period social accounting matrix (SAM). Unfortunately, in the CGE model intertemporal effects are ignored.

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. They 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:

$$Y(t) = F[K(t),A(t)L(t)] \dots\dots\dots (12)$$

Where t denotes time.

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. But at least since Malthus (1798) made his classic argument, many people believed that these considerations are critical to the possibilities for long-run economic 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, 2006). 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 (Romer, 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 $RGDP_t$ where as the proxy variables for climate change are represented by temperature and precipitation/ rainfall.

The model takes its form once again (see equation 4):

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

In logarithmic form it can be re-written as:

$$\ln Y_t = \beta_0 + \beta_1 \ln POP_t + \beta_2 \ln HC_t + \beta_3 \ln TEMP_t + \beta_4 \ln RF_t + \epsilon_t \dots \quad (13)$$

Where $\ln Y_t$ = Growth rate real GDP

$\ln pop$ = population growth rate

$\ln hc$ = growth rate of human capital

$\ln temp$ = change in temperature

$\ln rf$ = change in rainfall

ϵ = stochastic error term

CHAPTER FOUR

RESULTS AND DISCUSSION

In this chapter the researcher tries to determine a model with the application of econometric theories and various specification tests. By using the estimation methods described in chapter three, this part presents the econometric test results and outputs of the estimated model with their interpretations. It comprises 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.

4.1. Unit Root Test Results

In order to investigate whether the data series under study is stationary at levels or stationary in differences the current paper employed the Augmented Dickey-Fuller (ADF) test. 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. In all the three models of ADF test version the null hypothesis claims that the time series variable under investigation has a unit root or is a non-stationary process. In contrast, the alternative hypothesis states that the series has no a unit root or is a stationary process. Following this procedures the results for the estimations are presented in the table 4.1(See 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 at right 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 b/n zero & 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. For instance, if it is significant at the 95% level, then we have $p < 0.05$. Likewise, if it is significant at the 0.01 level, then $p < 0.01$. Furthermore, if $p < 0.0000$, our coefficient is significant at the 99.99+% level. 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 or non-sensual results. In order to solve this kind of non sense regression problem, all the series should be differenced. After taking their first difference of I(1) 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

As explained before, 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 conducting 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 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. To do so 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 Hannan-Quinn information criteria (HQIC) are the most widely used pre-conditions for lag selection. Thus, based on these lag selection criteria, lag 2 is selected for the model under consideration. (See Appendix-B)

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

4.2. Results of Johansen Co-integration Test

H ₀ : Rank	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 4.2, the null hypothesis of zero co-integrating equation against one or more co-integrating 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 4.3: 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 4.4: The results of Short run Dynamic model

Dependent Variable: LD-LRGDP			
Variables	Coefficient	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	-0.6261	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 4.4, 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. In the VECM specified in equation (11), 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 4.4, the lagged error correcting term (ECT-1) 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 4.2, 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:

$$\text{LRGDP}_t = 29.601 - 0.4814\text{LPOP}_t + 0.5349\text{LHC}_t - 0.6325\text{LTEMP}_t + 0.5428\text{LRF}_t \dots (14)$$

p-value [0.001] [0.000] [0.000] [0.003]

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 equation (14), 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 token a 1c⁰ 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) and Barro *et al.* (2003). The success of an economy depends in large part on the people with higher level of competence and in response they are becoming valuable assets of a country. The human capital includes “human as creator” who frames knowledge, skills, competency, and experience originated by continuously connecting between “self” and “environment”.

Through out the investment of human capital, an individual’s acquired knowledge and skills can easily transfer to certain goods and services (Romer, 1990). Currently, it is acceptable that the conceptual foundation of one’s human capital is based on ‘something like knowledge and skills’ acquired by an individual’s learning activities. Such accumulation of human capital through learning activities significantly influences many sectors. In the macroscopic aspects, many researchers present that accumulation of one’s human capital on education and training investment largely affects the growth of an individual’ wage, firms’ productivity, and national economy (Denison, 1962; Schultz, 1961). Microscopically, Lepak and Snell (1999) show that firm’s core

competences or competitive advantage is induced by the investment of human capital entailed with value creating potential.

Hansson (2008) shows that OECD measurement on human capital is closely linked to international comparable statistics considering investment in human capital, quality adjustments, and result of education. Furthermore, the concept of human capital needs to be expanded toward 'human development' with one's wellbeing on health, knowledge, and standard of living. Today's key feature is to emphasize the 'humanware' approach, such as reinforcing the role of knowledge creator and human relationship creator to improve overall productivity, as opposed to the 'software/hardware', which would rather focus on downsizing, restructuring, and knowledge taker.

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 problems for most of the economists. One of these economists is Thomas R Malthus. In his model (1826), he 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 LDCs) growth and human capital (in general) are in line with the theoretical expectations and studies of scholars in the respective areas.

The Ethiopian economy is climate sensitive since agricultural sector depends on rainfall availability and an increase of temperature overtime retard economic growth- real GDP. Other studies support the findings of this paper: Dell (2008) 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, 0.4percent loss of growth occurred annually between 1977 and 2007 due to climate variability (James *et al.*, 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 Ethiopia and it requires a timely attention as well as action from all concerned bodies and stakeholders. Recent research with a paradigm shift has gone beyond the statistical artifacts scaling a certain functional relationship between growth and environment. Instead, the current effort in climate related problems showed that the political economy and governance issues are key determinants to a country's growth and environmental quality.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

This paper has examined the potential impacts of climate change on Ethiopian economic growth- real GDP using a time series data (1980-2012). In doing so 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 negative impact on economic growth measured by real gross domestic product. On the other hand, since Ethiopia depends on rain-fed agriculture which comprises more share of its GDP (43%), 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, Ethiopia alone can do very little with regard to controlling climate change as its share of GHG emissions in comparison to developed countries is small. Although the developing countries like Ethiopia 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 unaffordability 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 Ethiopia 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, Ethiopia 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 GHG 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, no time to stay and 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 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 GHGs by using alternative energy sources such as geothermal energy, hydrothermal energy, solar energy. Furthermore, building a strong Green Economy should be part and parcels 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 4.1: 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	I(1)
	with constant and trend	-0.866	-4.325	-3.576	0.9597	
	with no constant and trend	-2.575	-2.650	-1.950		
DLRGDP _t	With constant	-4.123	-3.716	-2.986	0.0009	I(1)
	with constant and trend	-5.631	-4.334	-3.580	0.0000	
	with no constant and trend	-2.719	-2.652	-1.950		
LPOP _t	With constant	-0.402	-2.445	-1.692	0.3495	I(1)
	with constant and trend	0.562	-4.325	-3.576	0.9969	
	with no constant and trend	-0.402	-3.675	-2.969		
DLPOP _t	With constant	-2.026	-2.449	-1.694	0.0065	I(1)
	with constant and trend	-4.861	-4.334	-3.580	0.0004	
	with no constant and trend	-3.682	-2.972	-2.626		
LHC _t	With constant	3.061	-3.709	-2.983	1.0000	I(1)
	with constant and trend	0.046	-4.325	-3.576	0.9947	
	with no constant and trend	-1.950	-2.650	2.193		
DLHC _t	With constant	-3.716	-2.986	-2.084	0.0025	I(1)
	with constant and trend	-3.580	-3.584	-4.334	0.0012	
	with no constant and trend	-2.652	-1.950	-0.689		
LTEMP _t	With constant	-1.471	-3.709	-2.983	0.5478	I(1)
	with constant and trend	-2.826	-4.325	-3.576	0.1875	
	with no constant and trend	1.017	-2.650	-1.950		
DLTEMP _t	With constant	-5.810	-3.716	-2.986	0.0000	I(1)
	with constant and trend	-5.721	-4.334	-3.580	0.0000	
	with no constant and trend	-5.631	-2.652	-1.950		
LRF _t	With constant	-2.986	-3.716	-3.699	0.4314	I(1)
	with constant and trend	-3.580	-4.334	-3.868	0.4562	
	with no constant and trend	-1.950	-3.754	-2.652		
DLRF _t	With constant	-3.699	-3.716	-2.986	0.0041	I(1)
	with constant and trend	-3.868	-4.334	-3.580	0.0034	
	with 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: 1983-2012

Number of obs = 30

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	381.543	56.856*	25	0.000	2.4e-15	-20.1028	-10.9075	-16.3663

Appendix-C

Lagranger-multiplier (LM) test

Lag	Chi2	df	prob > Chi2
1	19.0981	25	0.79239
2	23.2949	25	0.56035


Ho: no autocorrelation at lag order

Declaration

I, the under signed person, declare that this thesis is my original work and has not been presented for a degree in any other university and that all sources of material used for the thesis have been duly acknowledged. Besides, the Examiners' comments are duly incorporated.

Declared by:

Name: Teketel Hadero

Signature: 

Date: 19/10/2006.EC

Confirmed by:

Name: _____

Signature: _____

Date: _____



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