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Determination of the Impact of Climate Change on Economic Growth in Zimbabwe (1980-2011)

By

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ABSTRACT

This research was aimed at determining the role of climate change on economic growth in Zimbabwe. In addition, the study sought to determine the individual role of global warming and a reductionin rainfall on economic growth in Zimbabwe for the period 1980 to 2011. Climate change was captured through variability of rainfall and temperature. Distributed Lag model was used to regress GDP growth on population growth, human capital, investment and climate variables. The model was chosen based on its ability to capture the overlapping rainfall pattern in Zimbabwe as well as to meet the implications of endogenous growth model, which the study is based. The results showed that rainfall has a positive relationship with economic growth while temperature is an insignificant determinant of economic growth in Zimbabwe. The results show that Zimbabwe is not being severely affected by climate change as found by other studies. Though the effect is minimal, appropriate policies should be put in place to ensure that the economy is not dependent on climate sensitive sectors.

ACRONYMS

ACF	Auto-Correlation Function
ADF	Augmented Dickey Fuller
CLRM	Classical Linear Regression Models
CO2	Carbon Dioxide
DL	Distributed Lag
ESAP	Economic Structural Adjustment Programme
GCM	Global Circulation Models
GDP	Gross Domestic Product
GHG	Green House Gases
GIM	Global Impact Models
GNU	Government of National Unity
IAM	Integrated Assessment Models
IMF	International Monetary Fund
IPCC	Inter-Governmental Panel on Climate Change
OLS	Ordinary Least Squares
UNFCCC	United Nations Framework Convention on Climate Change
WB	World Bank
ZIMSTAT	Zimbabwe Statistical Agency

Contents

CHAPTER ONE: Introduction and Background to the Study

Introduction

The problem of climate change has become a global phenomenon which has attracted the attention of Governments. Climate change is defined as a long term shift in weather conditions identified by changes in temperature, precipitation, winds and other indicators[1].It can be simply definedas any long-term significant permanent change in the "average weather" of a given area or region.It manifests itself through increase in theoccurrence and intensity of droughts, flooding, and storm damage among other weather events. On the other hand, real economic growth is defined as the increase in value of goods and services produced by the economy over timeholding prices constant (IMF[2],2012).

This dissertation sought to determine the impact of climate change on economic growth in Zimbabwe. The impact of climate change is severe toZimbabwe due to its heavy dependence on rain-fed agriculture and climate sensitive resources (Chagutah, 2010). Agriculture production consists about 17% of GDP according to ZIMSTAT figures. In addition, manufacturing sector which contributes almost the same share to GDP is highly dependent on agriculture production. Studies by Unganai (1996) and Mano & Nhemachena, (2007) confirmed that climate change has a negative effect on agriculture. Unlike micro studies mentioned above, this study focused on the role of climate change on macro-economic performance in Zimbabwe as measured by GDP.

To achieve the objective of the study, endogenous growth model wasused. The model was augmented by climate variables which are temperature and rainfall to capture the impact of climate change. Climate has an effect on all facets of life. It affects capital stock and capital formation which is essential for economic growth. Most importantly it affects the interaction of labour and capital in the production process hence the use of the endogenous growth framework.

[1] Definition obtained from the following Canadian website www.climatechange.gc.ca on the 8th of May 2014.
[2] Definition obtained from IMF (2012) through Wikipedia on www.en.wikipedia.org/wiki/ecoconomic_growth#cite_note-1

Background

Zimbabwe is a land locked country, located in the southern part of the Sub-Saharan region. It covers an area of 390 987 square kilometres. The country,wholly sits in the tropical region characterised by limited and erratic rainfall pattern averaging around 655mm. Rainfall season stretches from Octoberto March with January being the peakintercepted by 4 to 5 dry spells. The country is divided into 5 natural different regions.Region 1 receives more rainfall and more suitable for farming while natural Region 5 is dry and suitable for ranching in terms of agriculture activities.

Annual average temperature ranges from 15°C in high areas to above 25°C on low ground, (Climate Handbook of Zimbabwe, 1981). Notable is the hot season which stretches from mid-August to mid- November with hot day time temperature range of 26°C to 36°C.

ZIMSTAT sets the size of the Zimbabwe economy to above US$7.4 billion in 2011 as measured in real value terms. The economy is anchored on four main sectors which are agriculture, manufacturing, miningand tourism which had a share of GDP of about (16%), (19%), (4%)and (16%),respectivelyfor the period 1990 – 2011, (ZIMSTAT). The trend is almost the same for the period 1980 to 1990 though agriculture was the major contributor followed by manufacturing.

Agriculturesector contributesaround 40% of total export earnings and provides employment and income to 60-70% of the population. The sector supplies about 60% of the raw materials to the manufacturing sectorfor instance to food processing, milling, beverage, and textile industries. On the other hand, the sector relies on inputs from the manufacturing sector such as irrigation equipment, agriculture mechanisation equipment, fertilisers, chemicals and seeds, among others.

Zimbabwe's Economic Performance (1980-2011)

The Zimbabwe's economy was characterised by mixed growth performance for the period 1980 to 2011. The first decade of 1980-1990 experienced mostly positive growth rates averaging at 5.5% though negative growth rates were witnessed in 1982 and 1983 due to drought. This decade was relatively stable in terms of weather variability with rainfall usually above the average for most of the seasons.

The 1990-2000 decade was characterised by low growth rates, averaging 0.6%. Low growth rates may have been attributed to climate conditions and adverse effects of policy reforms like The Economic Structural Adjustment Programme (ESAP) adopted by Government in the early 1990s. During this period, severe drought was witnessed in 1992 that seriously affected economic activity.

The period 2001-2008 was the worst period for Zimbabwe in its economic history where the economy contracted by an average of 5% every year over the period. This period witnessed severe climate developments such as unreliable rainfall pattern, pronounced increases in temperature, recurrent droughts and even cyclones.The episode was also characterised by political instability, poor corporate governance and other unfriendly policies that also hindered economic growth. Nevertheless, this study will only focus on climate developments.

Finally is the period of economic recovery, covering 2009 to 2012 with the coming of the Government of National Unity(GNU). The Zimbabwean economy grewby 5.4% in 2009 to reach its highest growth rate of 10.6% in 2011 following the adoption of the multicurrency system. Growth in this period was mainly due to the adoption of the multicurrency system and political stability otherwise climate was even more volatile. Performance of some sectors of the economy such as manufacturing and agriculture remained subdued asweather continued to be unpredictable with recurrent droughts, unpredictable rainfall patterns and high temperatures being experienced throughout the country.

Climate Developments in Zimbabwe

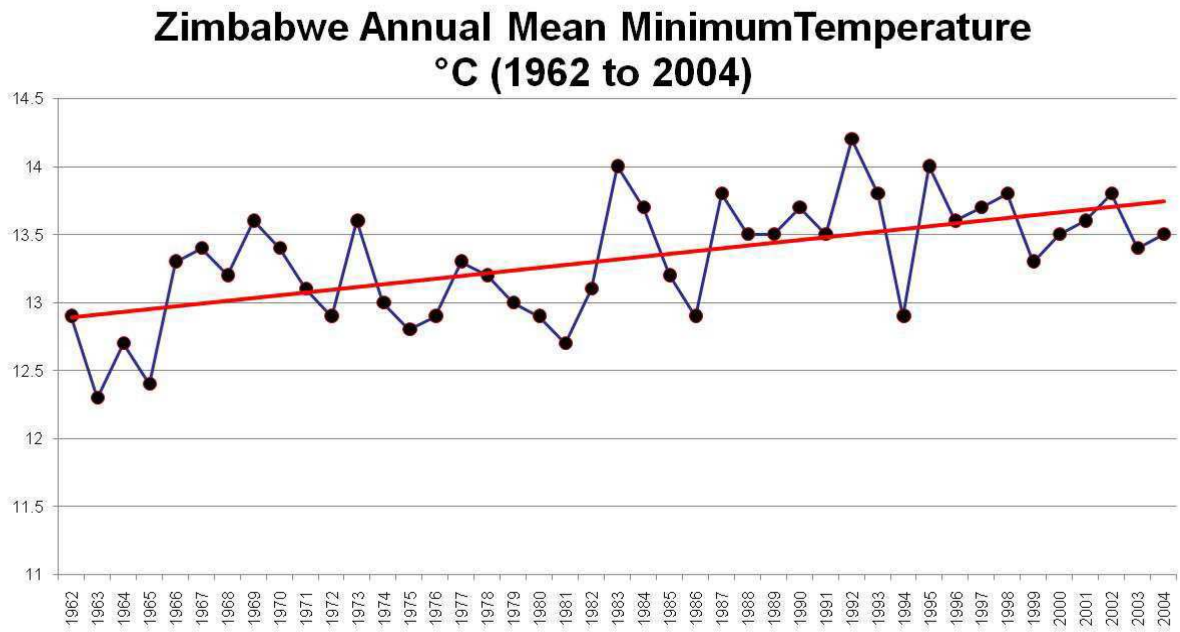
Historically, the country experiences one to three droughts every decade. This is mainly due to changes in the phases of the El~Niño-Southern Oscillation (ENSO) phenomenon and periodic sea surface temperature changes. This was more pronounced in the period 1980 to 1990 decade where drought was witnessed in 1982 and in 1986. The frequency has since increased starting from 1990 to date. In the decade 1990 to 2000 alone, six drought years were recorded in Zimbabwe according Meteorological Department.

In addition, increases in dry spells in the middle of the rainfall season have been witnessed towards the end of the period under study. These developments are associated with climate change. Zambuko[3] confirmed the presence of climate change in Zimbabwe. The presence of climate change in Zimbabwe was also supported by the fact that, temperature was on an

[3]The presentation was downloaded on following website: http://www.itu.int/ITUD/emergencytelecoms/events/Zimbabwe_2011/Climate%20Issues%20and%20Facts-%20Zimbabwe%20-%20Dept%20of%20Met.pdf on the 5th of September 2013 through Google.
C. Zambuko was a meteorologist by then with the Zimbabwe Meteorological Service Department on his presentation on Climate Issues and Facts: Zimbabwe.

upward trend as evidenced by data for the period 1962 to 2004 for both annual minimum and maximum temperatureas illustrated by Figure 1 below. From the presentation, warmest periods in Zimbabwe were recorded since 1987 meaning that climate change has become more severe of late than before.

Figure 1: Zimbabwe Annual Mean Minimum Temperature (1962-2004)



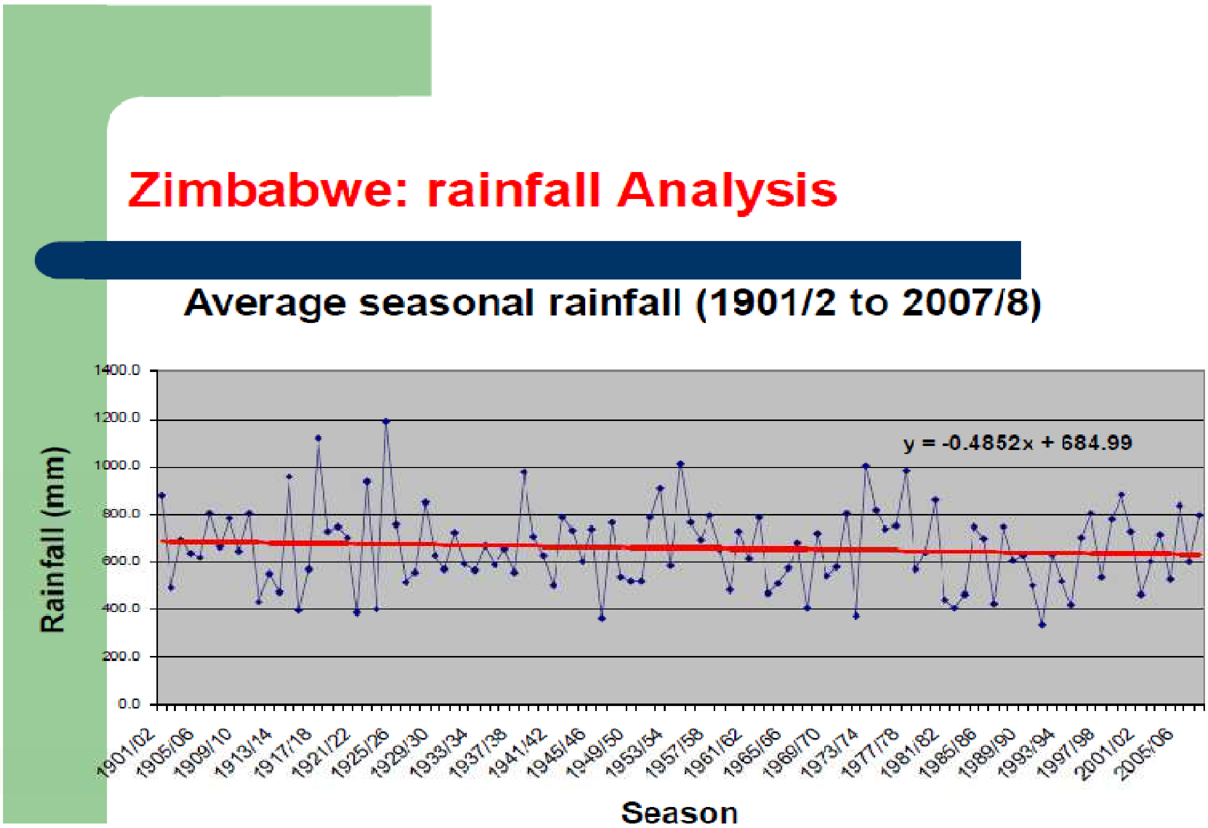
Adapted from Zambuko's Presentation

Figure 1 above shows that average annual temperature is on an upward trend. It rose from below 13°C in 1962 to above 13.5°C in 1995 and beyond. The Meteorological Department (Met Dept) estimates that daily minimum temperature has increased by 2.6% over the last century while daily maximum temperature has risen by about 2% over the same period.Annual mean temperatures have increased significantly by about 0.4°C since 1900. This development is consistent with Inter-Governmental Panel on Climate Change (IPCC),(2001) which noted that average global temperature has gone up by 0.6°C since 1901.

According to recent climate model projections, global temperatures are expected to increase by at least 2°C above pre-industrial levels by 2050. This is, even if global emissions of greenhouse gases fall, which can have broad impact outside of agriculture (Hsiang 2010). The increase in temperature has caused some regions to shift from their initial level to other levels like, part of region 1 becomes region two and so on.

Figure 2 below shows an analysis of rainfall pattern from 1901 to 2008. In the figure, the vertical axis(y) is rainfall measured in millimetres whilst the horizontal axis(x) is the rainfall season. It can be seen that rainfall trend is going down making it critical to analyse its potential implication on economic growth in Zimbabwe.

Figure 2.



Adapted from Zambuko's Presentation

From data it was noted that October and December are characterised by an increasing pattern of rainfall. On the other hand, November, January and March show a declining trend. This pattern is believed to be associated with floods and droughts. Furthermore, subsequent increase in frequency of droughts beginning 1990/1, 1991/2, 1992/1993, 1993/94, 1997/98, 2001/02, 2002/03, 2004/05 and 2006/07 were witnessed suggesting that climate change is taking place in Zimbabwe. However, it is important to note that it is difficult to easily identify the decline in annual mean rainfall becauseusually it is the distribution that is changing not the total rainfall received.

The climatic developments in Zimbabwe are in line with what is happening elsewhere in the world. For example, it was noted that snow covering Mt. Kilimanjaro and Mt. Kenya has declined by 50% since 1960. On Mt. Kilimanjaro, ice could be seen at a height of 2 700 meters above the sea level in late 1990s. It has since retreated to 5 685 meters above sea level as of 2001 due to increase in temperature and reduction of rainfall (Ngaira 2007).

The decline in rainfall and increase in temperature might have contributed to poor performance of the overall economy in Zimbabwe through its impact on agriculture, manufacturing, tourism and other sectors.

Climate Change and Economic Growth in Zimbabwe

As discussed earlier, Zimbabwe is an agro based economy,with the majority population dependant on agriculture as their source of livelihoods. The sector is heavily reliant on natural rainfall exposing the sector to climate change if no measures are put in place. The impact is also transmitted to other sectors of the economy like manufacturing through backward and forward linkages with agriculture.

Climate change does also affect the growth of the economy through its impact on water resources and health of the population. Water resources are critical for both economic production and health of the labour force which constitutes human capital. In addition, reduction on rainfall affects hydro power generation which is critical for production in Zimbabwe. Firewood is important source of energy for rural folks in Zimbabwe, however, with the changing climate trees are dwindling though there is bi-direction causality.

In Zimbabwe, it has been noted that drought years have been accompanied by negative GDP growth rates. This was witnessed in 1983/84 which was a drought year and GDP growth was -1.9%, again in 1991/92 there was a drought and growth was -7%. Similar situation was notedin Kenya when its economy lost up to 22% of Gross Domestic Product (GDP) from loss of production due to floods and droughts during the 1997-2000 El Niño and La Niña (Biemans et al. 2006). This development shade light on the potential impact of climate on economic growth in Zimbabwe.

There are signs of climate change in Zimbabwe as evidenced by the upward trend of temperature as well as decline in rainfall pattern. The authorities seem to be aware of this development and its potential impact on economic performance. However, there is no enoughresearch on the subject to determine the role of climate change on economic growth in Zimbabwe.

Problem Statement

Having noted that climate is changing, the challenge is to ascertain its real impact on economic growth in Zimbabwe. Drought was found to be associated with negative growth rates, however, there is little research to determine the quantitative impact of climate change on growth in Zimbabwe. There are regional studies that were done that found a negative relationship between climate change and economic growth but those are general conclusions. Country specific studies will provide more detail on the magnitude of the impact of climate change in Zimbabwe.

A number of micro studies on the subject were done particularly on impact of climate change on agriculture in Zimbabwe. Amongst them are Mano and Nhemachena (2007), Makhado (1996) and others who all found a negative impact. These studies ignore other sectors which if combined contribute more to GDP than agriculture alone.

Empirical studies by Dell et al. (2008) and several others, emphasised the increase in temperature as more detrimental to economic growth than decline in rainfall. Nevertheless, Zimbabwe is an agro economy, therefore it needs to be determined if temperature has a greater role to play in determining growth. This is more important given the close positive relationship between rainfall pattern and economic growth being witnessed in Zimbabwe.

This study therefore sought to estimate the quantitative impact of climate change as proxied by temperature and rainfall on economic growth. In addition, it sought to determine the climate variable between temperature and rainfall that has more impact on economic growth taking into account the economic structureof Zimbabwe.

Research Objectives

1. To investigate the role of climate change on economic growth in Zimbabwe.
    a) To determine the impact of temperature change on economic growth in Zimbabwe over the period 1980 - 2011.
    b) To determine the impact of rainfallchange on economic growth in Zimbabwe over the period 1980 - 2011.

Research Questions

1. Does climate change negatively affects economic growth in Zimbabwe?

2. Doesglobal warming (temperature increase)affect economic growth in Zimbabwe?
3. Does rainfall decrease have an impact on economic growth?

Hypothesis

The main hypotheses to be tested in this study are that:-

1. Climate change as represented by climate variability negatively affects economic growth.
2. Temperature increase affects economic growth more than decrease in rainfall.

Justification of the Study

The Government of Zimbabwe has proceeded to sign several climate change protocols withclimate change organisations such as United Nations Framework Convention on Climate Change (UNFCCC) without adequate information on the impact of global warming to the overall economy. It will be beneficial for policy makers to negotiate on the international arena in future guided by facts from researches on the subject.

Also, as the Government prepares to come up with climate change strategy policy, it requires research based facts to come up with meaningful plan. Currently, research is limited to few sectors especially on agriculture. Extrapolating findings from regional and similar countries is an alternative but they may not be exactly the same with actual local results.

Zimbabwe has been experiencing food shortages for the greater part of the period under study. The shortage could be attributed to climate change, which if it is true, appropriate measures have to be put in place as this is threateningfood security and economic growth. Climate change is also associated with increase in incidence of diseases such as malaria which affect the labour force productivity and eventually economic growth. UNFCCC (2001) noted that they are close linkages that exist between climate change and agriculture production as well as employment and overall GDP.

As already found by Akram (2012) and others, global warming as represented by increase in temperature is a threat to economic growth. If this finding is wrong in the Zimbabwean context, this could result in inappropriate polices being adopted. Against this background, this empirical study sought to identify climate variable that is of concern to Zimbabwe's economic performance. This will help in adopting most appropriate policies to mitigate and adapt to climate change.

Methodology

The study employs a single equation method in the context of endogenous growth model. We incorporate climate variables (temperature and rainfall) into the endogenous growth model.Secondary data collected from ZIMSTAT, World Bank and Meteorological Departmentwas used for the purposes of this study. Distributed Lag Model is used in the empirical model. The model was chosen on its ability to capture the implication of the endogenous model as well as the overlapping rainfall season in Zimbabwe.

Organisation of the Dissertation

The rest of the study is organized as follows. Chapter one presents the introduction and background of the study. Theoretical, Literature Review is presented in chapter two. Chapter three discusses the methodology,data and estimation methods while chapter four presents the results of this study. Chapter five concludes this study by proposing recommendations and policy implications.

CHAPTER TWO: Literature Review

Introduction

This chapter concentratesontheoretical and empirical literature on climate change and economic growth. The first part of the chapter explains the transmission mechanism of climate change to economic growth in Zimbabwe. This is followed by the model to be used in this study andreview ofempirical literature. The chapter ends by discussing alternative models that can be used or were used by other researchers to solve the same problem.

How Climate Changemay affect Zimbabwe's Economic Growth

The effects of climate change to economic growth in Zimbabwe areboth negative and positive.The effects depend on the nature of climate change and the place affected. In cold areas like in natural Region 1, places like Nyanga, global warming is being associated with increasing rainfall.This development results in an increase in agriculture production. This positively affects economic growth through increased supply of food and raw materials to the manufacturing sector. The overall effect is to increase income, consumption and even savings that will further drive growth.

On the other hand, increasing temperature accompanied by decrease in rainfall being experienced in some places of natural Region 5 results in decline of output.This scenario has the effect of decreasing employment, production and income in most sectors especially the agriculture and manufacturing sectors.

Furthermore, warming of very cold areas is likely to increase labour productivity contrary to hot areas which is likely to experience the opposite. This view was also found by Dinar & Sanghi (2001)andMendelsohn & Williams (2004), who concluded that climate change is not always that bad as it benefits cool areas. Increase in productivity of labour results in economic growth.

The economy of Zimbabwe, however, is such that agriculture is the back-borne with majority in rural area and few in urban areas dependent on the sector. In Zimbabwe, the most affected sectors of the economy include agriculture, environment and tourism, manufacturing, energy and water resources. These sectors are almost similar to six main sectorsidentified by the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC 2007) as mostly affected by climate change. These are: ecosystem, food, water, health, coasts,industry, settlement and society. The resultant effect of climate change on economic growth varies from place to place but generally, negative effect is expected in Zimbabwe.

Agriculture and Food Security

One of the major victims of climate change is agriculture production. As discussed earlier, climate change manifests itself through changes in temperature and rainfall pattern among other events. Rainfall and temperature are some of the basic ingredients of agriculture production especially rain fed farming. Reduction in rainfall is likely to result in low output as some crops fail to ripe. Also excess rainfall can damage crops and animals resulting in low output. High temperatures affect crop production and animal husbandry in hot areas though it may improve output in cold areas.

Rosenzweig et al. (2002), noted that vulnerableareas are expected to experience losses in agricultural productivity, primarily due to reduction in cropyields especially,in developing countries. The impact on crop yields, agricultural productivity and food securityvary depending on the types of agricultural practices and systems (Watson et al. 1997). The impact is severe in Zimbabwe, where agriculture contributes a huge share on total output.

Basically, climate change has negative effects on agriculture production that has an impact on aggregate demand through low incomes andfood supply resulting inreduced inputs for production in the secondary industry.

Water Resources

Water is critical if economic growth is to take place as it is one of the key economic enablers. Climate change is generally associated with reduction in rainfall threatening human life and production in Zimbabwe due to under utilisation of ground water thatwould substitute natural rainfall. It has resulted in decline of water reservoirs in Zimbabwe. Water shortage in Bulawayo is one of the reasons behind company closures being experienced currently.In other countries, Parry and others (2007) notedthat a decline in water supplies stored inglaciers and snow cover due to global warming is increasing water scarcity.

Decline in natural rainfall accompanied by increasing temperature due to climate change has caused afall in water bodies in Zimbabwe as some rivers and dams dry up.The effect of this development is that, it reduces food supply, agriculture production and subsequently labour productivity. This eventually translates to low economic growth.

Energy Generation

Hydropower is one of the important sources of energy in Zimbabwe. However, with the changing climate, low levels of rainfall are likely to threaten hydropower generation reducing energy supply to production units. Low energy supply has serious effect on the cost of production, and even to the health of human beings. Hydropower is important as it is relatively cheap to produce and is safe in terms of GHG emissions.

The implication of power shortage is the increase in cost of production across almost all sectors of the economy. The resultant effect is the decrease in production leading to unemployment, low aggregate demand and subsequently, low economic growth. Stern (2006) and World Bank (2007), noted that high frequency of droughts changes hydropower production, and increased floods can significantly result in the need for public investment in physical infrastructure starving others areas.

Health

Health is one of the components of human capital that is critical for economic growth. Extreme weather events, floods and droughts which come with climate change promote the spread of infectious diseases via contaminated water or food such as malaria, cholera, dengue, typhoid and diarrhoeal(Martens and others, 1999). Some of these diseases are associated with below and above normal rainfall pattern which are common with climate change. Droughts promote malnutrition especially in prone regionslike Masvingo and some parts of Mashonaland Central. The increase in diseases and deaths reduces productivity of the labour force affecting economic growth. In addition, the increase in disease burden diverts resources to consumption instead of investment threatening the growth of the economy in the medium to long term.

In other countries, heat waves and cold weather which might be attributed to climate change are killing human kind or resulting in physical injury especially the poor and the elderly reducing available and future human capital. Extreme cold weather also results in increased power consumption which usually comes from thermal power station that contributes further to GHG emissions. However, positive benefit from global warming is expected from reduction in cold related deaths. Notwithstanding this benefit the overall effect is expected to be negative.

Tourism

Tourism is one of the drivers of growth in Zimbabwe. It is an essential sector as it usually requires minimum initial capital outlay. In most cases, the sector attracts tourists due to natural endowments and environment. It is driven by factors like environment (wild animal, weather) and other manmade structures, among others.

Floods and droughts have a severe effect on the environment of Zimbabwe. Droughts destroy wildlife which may increase tourism activity in the short term but in the long term may lead to extinction of certain wildlife animals. Floods have an effect of destroying structures that may be attractive to tourists reducing the activity of the sector. Increase in temperatures threatens the extinction of certain wild plants and animal reducing tourist attractiveness of any place. Tourists from very cold country would be visiting hot countries for sun basking but with increase in temperature this reduces this kind of tourism.

Reduction in tourism activity results in unemployment of those in the sector causing reduction in incomes and ultimately economic growth. The overall effect of climate change on tourism is not clear because it can be either way.

Manufacturing

Manufacturing is not directly related to changes in climate. However, it is heavily dependent on agriculture for inputs and also supplies its output to the agriculture sector as inputs. This relationship is more pronounced in Zimbabwe where manufacturing is mainly for low cost products mostly from agriculture inputs. These backward and forward linkages of the manufacturing sector with agriculture and energy sectormeans that a climate shock that affect primary industry also affects the activities in the secondary industry.

The nexus between climate change and economic growth is complex and difficult to exhaust. Having outlined some of the channels through which climate change affect economic performance, the combined effect can be captured through economic performance as measured by GDP growth. Generally, climate change affects countriesdifferently through various channels depending on geographical and socio-economic status of any given country. Sub-SaharanAfrica, is more vulnerable to an increase in climate variability due to its socio-economic status and geographical location (Thurlow, 2009).

To simplify the several channels through which climate change affect economic growth, we concentrated on their ultimate effect on labour, capital formation, human capital and interaction of these factors of production. Fankhauser and Tol, (2005), concluded that climate change reduces capital formation and saving,resulting in reduced economic growth. Production can be modelled as function of inputs, therefore economic growth was also modelled as function of changes in factors of production. The major assumption is that climate change negatively affects capital formation. Decrease in capital formation reduces capital stock, consumption and ultimately economic growth. It also reduces technical progress, labour productivity and investment in human capital. The overall effect is to suppress growth of the economy.

Macro Studies on the Role of Climate Change

Endogenous Growth Model

There are various methods that were used to model the impact of climate change on growth. Some of them included the endogenous growth model, computable general equilibrium (CGE) models and integrated assessment models (IAMs), among others.

In this study, endogenous growth model was used. It is a brain child of Romer (1986) and Lucas (1988). It asserts that long run economic growth is determined by forces that are internal to the economic system. The forces include improvements in productivity due to a faster pace of innovation, learning by doing, knowledge spillover and extra investment in human capital.

It is a refinement of the Solow-Swan (1956) Model. The Solow-Swan growth model is built on the assumption of constant savings, only two factors of production capital and labour. Growth is mainly determined by technological progress that is exogenously determined and high rate of savings. Solow-Swan (1956) model is specified as follows:-

$$Y = AK^{\alpha} L^{\beta} \quad \text{.........} \quad 1$$

Where, Y is output, K is physical capital, L is labour, A is technological progress (TP). α, β measures returns to scale which in this case are equal to one meaning that, doubling of all inputs results in output doubling.

The neo-classical growth modelattributes higher growth rate to higher savings in the short run while in the long run,to changes in technological progress. Eventually, the growth of theeconomy will reach steady state, where savings will be equal to depreciation and no further growth. The implication of the neoclassical growth model is that in the absence of shocks, income per capita for poor and rich countries converge in the long term (Barro 1989).

Unlike the Solow-Swan (1956) growth model that has exogenous technological progress the endogenous growth model has technological progress that is embedded in both capital and labour. The fact that TP is embedded in capital and labour makes growth to be determined within the model and not exogenously as in neoclassical growth model.

The neoclassical growth modelfails to explain how technological progress comes about but probably from thin air which is not plausible. Additional investment at steady will only result in decline in production due to diminishing returns. This assertion failed to hold empirically when developed countries continued on a growth path while developing countries were slowing down in terms of growth. This convergence hypothesis was found to be inconsistent with cross country evidence (Barro 1989). The outcomecalled for further research on the subject to investigate the reality of this theory.

The neoclassical growth model also suffered from its assumptions such as constant saving rate which is less realistic as economic agents change their saving behaviour depending on circumstances. Another weakness is its assumption that growth will eventually reach a steady state where growth reaches the zenith which was proven to be wrong by later empirical studies.

The major refinement of the endogenous growth model from the Solow-Swan Model is the inclusion of human capital as additional factor of production to capital and labour. The model was developed to address the weakness of the Solo-Swan (1956) growth model by trying to identify the sources of technological progress and the reason behind the divergence in incomes per capita between rich and poor countries.

Lucas (1988), specifiesthe endogenous growth model as follows:-

$$Y = K^{\alpha} L^{\beta} H^{\chi} \quad \ldots\ldots 2$$

Where, Y output, K is physical capital, L is labour, H is Human capital and α, β, χ measures returns to scale, their summation exceeds one. Returns to scale exceeds one meaning that doubling of inputs results in output more than doubling.

Endogenous growth model attributes technological progress to the rate of capital growth.Ascapital level increases technological progress also take place. The driving force behind TPis learning by doing by the labour force and the desire for firms to be competitive so they look for alternative low cost production methods. This assertion seems plausible when compared to the neoclassical model which assumes that technological progress is exogenously determined.

Human capital as defined in endogenous growth theory is basically composed of educated and healthy labour force. Educated labour force is able to learn new methods of production through learning by doing and can even help in identifying better methods of production that enables continuous increase in productivity. In essence, knowledge accumulation and spillover plays a greater part in explaining persistent growth rates. The inclusion of human capital was able to account for persistence in growth of rich countries.

The assertion of the model appears to be meaningful in that uneducated labour force is less productive as it cannot fully employ capital. In addition, it is reasonable to assume that labour productivity increase with time through learning by doing or through learning from others.

Due to the possibility of continuous increase in productivity, the factors of production do exhibit increasing returns to scale meaning that doubling factors of production results in more than doubling of output. Resultantly, the model predicts the possibility of divergence of income between the poor and rich countries because growth does not reach the steady state which is more realistic.

The two models, neoclassical and endogenous growth model implicitly assumed that climate has little or constant effect on factors of production over time. Changing climate overtime may mean that doubling of inputs may not result in doubling of output. This may be due to decline in productivity in inputs attributed to changing climate conditions.

In this study,climate variable was incorporated into the endogenous growth model to try and estimate the impact of climate change on economic growth in Zimbabwe. The use of the endogenous growth model follows the dynamic function approach where various growth models are used to analyse the impact of climate change.

By incorporating the climate component into the endogenous growth model in equation 2, the following model is derived.

$$Y = K^{\alpha} L^{\beta} H^{\chi} C^{\delta} \ldots\ldots 3$$

Where, Y is output, K is physical capital, L is labour, C is climate, H is Human capital and $\alpha, \beta, \chi, \delta$ measures the effect of a change in their respective variable on output and their summation is assumedto exceed one in line with the assumption of the endogenous growth model.

The incorporation of the climate component is based on the assumption that capital, labour and human capital are not sufficient to explain the growth because climate developments have also a bearing on the productiveness of all the above three factors of production. Increase in temperature may reduce labour productivity or floods can destroy capital, all having an effect on growth of the economy (Montesquieu, 1750; Marshall 1890;Huntington 1915).

Using the above mentioned methodology, Akram (2012) and Dell et al.(2008), carried out a research to determine the relationship between climate change and economic growth. The study by Akram (2012) was motivated by the need to analyse the effects of changing weather patterns on economic growth in Asian countries.

Asian countries are home to about 60% of the world population. The continent also happens to be harbouring some of the emerging economies like China and India that are now producing significant amount of emissions. Furthermore, the continent supports a huge number of poor farmers who depends on agriculture, making them vulnerable to climate changes like in Zimbabwe.

Akram (2012), used the following variables human capital, urbanisation, population growth and then added climate variables that are precipitation and temperature to the production function to capture the role of climate change. Urbanisation is one of the variables believed to drive growth in addition to traditional variables (labour and Capital) (Hughes and Cain, 2003). The relationship between economic growth and urbanisation was found to be around 0.85 (Henderson, 2003).Based on this, it is reasonable to include urbanisation variable into the model as done by Akram (2012). However, its applicability in Zimbabwe is limited as the economy was characterised by high rate of urbanisation accompanied with low growth for the period under study.

Other variables, population growth, human capital, precipitation and rainfall are helpful in this current research in modelling the impact of climate change in Zimbabwe. The methodology is fairly simple and easy to apply in the Zimbabwean context.

Results from study by Akram (2012),indicated that human capital and urbanisation had a positive impact on growth while population growth had a negative effect. On the other hand, increase in precipitation and decrease in temperature had a positive effect on economic growth and the reverse was true. This means that, climate variability had a negative effect on growth.

On individual sectors, human capital was found to be statistically significant at 5% with a positive effect on all sectors especially on manufacturing and services sectors than on agriculture.Other variables (temperature, precipitation and population growth) had a negative effect on all the sectors. Agriculture was the most affected by climate change through decline in rainfall than increase in temperature of the three sectors used in the study.

Findings by Akram (2012) confirm that some sectors are more vulnerable to climate change than others especially agriculture.In addition, overally, temperature increase was found to be more harmful than decline in rainfall which may not be the case in Zimbabwe taking into account its economic structure.

In the same vein,Dell et al. (2008), used the same methodology to investigate the relationship between climate change and economic growth over a period of 50 years throughout the world focussing specifically on 125 countries. The major question of the study by Dell et al. (2008) was to determine the relationship between temperature shocks and economic growth. To answer the question, Dell et al. (2008), utilised the production function approach todetermine the role of temperature and precipitation on aggregate economic growth.The study by Dell et al. (2008) raises the question on the role of temperature in affecting growth in Zimbabwe compared to rainfall.

In doing the research, they took into account that the long term effects of climate change may not be the same in the short and long runas people tend to adapt in the long term reducing the long term effects. In looking at variability of annual mean temperature, fluctuations were noticed of about 2-3°C. The researchers noticed that fluctuations were more pronounced in cooler countries and the trend was generally going upwards signifying climate change.

Variations in precipitation were noticed much on driest regions relative to wet regions and it was also found to be more volatile than temperature.

Dell at al. (2008), identified two possible ways in which temperature could affect economic activity. The first one is through affecting the level of output like affecting agricultural yields and the second is through reducing the economy's ability to grow by reducing investment and institutions that influence productivity growth. This conclusion is plausible as it points out to direct and indirect effects of climate change on growth. However, it is important to note that the research gave much emphasis on temperature as the climate variable that affectseconomic growth than rainfall.

Results from the regression show that a 1% increase in temperature leads to 1.09% decrease in growth of poor countries and with negligible effect on rich countries. The impact of precipitation was found not statistically significant on both poor and rich countries.An increase by 100mm of annual precipitation was associated with a 0.08 percentage point lower growth rate in rich countries and an statistically insignificant 0.07 percentage point higher growth rate in poor countries. These results highlight the role of rainfall on poor than rich countries. Though, the rainfall variable was statistically insignificant on poor countries from the study, its sign was positive bringing out the role of agriculture to developing countries.Statistically insignificant rainfall variable might not be true to Zimbabwe as the economy is agro based such that rainfall is the one that may have a serious impact on growth and not temperature. In light of this, it becomes difficult to apply the results to Zimbabwe.

Similar results were found by Odosulo et al. (2009) using the endogenous growth model. The study covered 34 African countries for the period 1961-2009. They basically followed the framework of Barro (1991), Levine and Renelt (1992) and Sala-i-Martin (1997b) where they modelled economic growth as the dependent variable. On the exogenous variables, usual determinates of growth were included plus the widely used climate variables (temperature in this case). Odosulo et al. (2009) sought to ascertain the role of temperature in predicting Africa's economic growth. They also wanted to find other factors that are behind differences in growth rates on selected countries. Again in this study, the role of temperature is prominent unlike rainfall.

Their findings showed that a 1% increase in temperature results in 0.27% decline in GDP for all the 34 countries. However, a higher impact of 0.47% was witnessed when the period is reduced to 2000 instead of 2009. The decline in the impact for longer period is attributed to some form of adaptation that takes place especially by larger economies like South Africa and Nigeria. Countries that were most affected according to this study include Zimbabwe, Algerian,Zambia and others while the least affected are Rwanda, Uganda, Sudan and Chad.

The role of temperature over rainfall was emphasised in the study by Odosulo et al. (2009). This left a gap for a study to be done that focuses on rainfall as potential climate variables that affects growth most compared to temperature. Also important is the findings by Odosulo et al. (2009)that the impact of climate change is severe in shorter periods as people tend to adapt in the long run.Even though climate is the study of weather over a long period, the effects of climate change appear to be inversely related to time. In view of this, the present study focussed on the period of only 31 years instead of several decades.

The results of the three studies discussed above are basically the same but Akram (2012), concluded that both temperature and precipitation significantly affect economic growth of the poor countries unlike Dell et al. (2008) and Odosulo et al. (2009) who concluded that only temperature has a significant impact. One of the similarities of the studies is that, all were done for several countries at once that is panel research. However, Akram (2012) and Odosulo et al. (2009), did not try to separate the poor and rich countries to see if the results will be different as was done by Dell et al.(2008).Both Akram (2012) and Odosulo et al. (2009) focused on regions that may share a lot in common in terms of weather unlike Dell et al. (2008) who focused on the whole world. The methodology employed is basically the same though the coverage of their studies is different.

Studies by Akram (2012), Dell et al. (2008) and Odosulo et al. (2009), confirms the presence of climate change and its impact on economic growth across the world. In this regard, the current study noted the usefulness of the model used and borrowed some important elements from the above discussed studies.

However, the current research noted that the exogenous variables used do not fully capture the implication of endogenous growth model. This is so, because endogenous growth theory implies that labour and human capital productivity, increase with time through learning by doing. To capture this phenomenon, lagged variablesof the exogenous variables should be included in the model.

Alternative Models

In the current study, endogenous growth model was chosen to determine the impact of climate change on economic growth in Zimbabwe due to its simplicity and realistic of its assumption. However, there are alternative methods that have been used for the same purpose discussed below with their limitations.

Ramsey-Cass-Koopmans Model

This model is a brain child of Ramsey (1928), Cass (1965) and Koopmans (1965) popularly known as the Ramsey-Cass-Koopmans Model. It is an extension of the Solow-Swan (1956) model but revised the assumption of constant saving. In this model, savings are endogenously determined by explicitly modelling the consumer's decision to consume or saving unlike in the Solow Swan model. All other assumption remains the same as in Solo-Swan model.

Using theintertemporal saving and investment decisions of the Ramse-Cass-Koopmans model,Elshennawy at al. (2013) did a study in Egypt to determine the relationship between climate change and economic growth.

Empirically,Elshennawy at al. (2013) used theMulti-Sectoral Intertemporal General Equilibrium Model. The results were that in the absence of any adaptation measures, GDP will decline by 10% in 2050 while with adaptation measures it will only fall by 4% by the same date in Egypt.

Enumerative Approach

This is an approach whereby, the impact of climate change is analysed sector by sector, for example on agriculture or health or tourism. In this approach,the physical impact of climate is estimated using laboratory experiments and impactmodels. The physical impacts is given a price or value then added up for all sectors of the economy. The value of the impact are then evaluated together to obtainan estimate of the total change in economic growth stemming from climate change(Nordhaus, 1991; Cline, 1994; Tol, 1995). The approach ignores inter-temporal effect and only focus on single period effects thereby failing to provide how climate change affects economic growth in the long run.

The results are physically realistic and easilyinterpreted (Tol, 2009). However, it ignores horizontal sectoral linkages such as the interaction of sectoral impacts.It has also the weakness of extrapolation.

Micro Studies on Climate Change and Economic Performance

Ricardian Approach

The Ricardian Approach, named after its founder David Ricardo who developed it based on the assumption that farm value reflects the productivity of the farmland (Mendelsohn & Dinar, 2003). The basis of the model is that, in a well-functioning market, the value of land reflects its profitability.

One of the strength of the Ricardian Approach is that, it automatically incorporates the adaptation by farmers. For example, if a wheat farmer noticed that the prevailing climate favours soya bean production, then a farmer as a rational economic agent will shift to soya bean production (Polsky, 2004). This is an important attribute of this model as it really captures what economic agents do, sometimes unknowingly.

However, the approach has its flaws with one of them being that it assumes prices are constant resulting in a bias in welfare calculation. Cline,(1996) noted that including price effects is problematic and that the Ricardian Approach is weaker inthat respect. It also suffers from its assumption of the existence of well-developed functioning markets of land which might be unrealistic because Government usually intervenes in this type of market making them inefficient.

Mano and Nhemachena, (2007) used the approach to assess the impact of climate change in Zimbabwe for the farming season 2002/3 and 2003/4 using primary panel data covering 700 households from 8 provinces. Mano and Nhemachena, (2007) regressed net farm revenue per hectare on climate, hydrology, socio-economic and soil variables. Precipitation and temperature variables were used as proxies of climate.

The results indicated that both climate variables were statistically significant with precipitation having positive sign and temperature with negative sign. This means that an increase in precipitation increases agriculture production while an increase in temperature reduces production. The findings of this study, serves to confirm one of the transmission mechanisms of climate change that is through agriculture. Agriculture is one of the sectors that contribute significantly to overall GDP growth rate in Zimbabwe.

Elsewhere, Seo and Mendelsohn (2007) in South America,Ouedraogo, Somé & Dembele (2006) in Burkina Faso used the same model andmethodology andfound similar results. Quedraogo et al. (2006) and Nhemachena et al. (2007), used farmland revenue and focussed on single country unlike Seo et al (2007) who used actual land value and focussed on the whole region. However, the results are all similar, confirming that climate change negatively affects agriculture production. Also similar results were found by Jain, (2006) in Zambia and Deressa (2007) in Ethiopia using the same approach.

Individual Crop Studies

Davis and Sadiq, (2010)carried out a research on the effect of climate change on cocoa yield in Ibadan, Nigeria over 10 years, 1999-2008. The research employed regression and correlation analysis on cocoa production and climate variables (temperature and rainfall). The study discovered that the degree of correlation between climate variables and cocoa production was 0,25.

The results also found that temperature and rainfall accounted for 6,2% of cocoa yield and a weak inverse correlation in rainfall of (0.0073), implying that increase in rainfall result in decrease in yield in Nigeria. The study concluded that a combination of optimal temperature and minimal rainfall give a better yield and improve production.

Similar studies were done byKimengsi and Tosam,(2013) and Makadho (1996) in different countries for individual crops. Their findings are consistent with Davis and Sadiq, (2010), who also found that climate change have a negative effect even on individual crops.The findings are important to Zimbabwewhere crops constitute the greater part of agriculture. The studies give the micro build up of the impact of climate change on the economy from sub-sectors.

Study on Livestock

Seo and Mendelsohn (2006) used the Ricardian Approach to assess the impact of climate change on livestock management in Africa. The results showed that an increase in global warming has more negative effect to large scale farmers compared to small scale due to easy of adaptability and diversification by small scale farmers.

The studies on agriculture production help to shade light on the impact of climate change on economic growth to agro dependent economy, Zimbabwe. If agriculture is vulnerable as illustrated by the above studies then a study to Zimbabwe would be important as well.

Relationship betweenCountry Location and Climate Change

Mendelsohn et al. (2004) did a research of comparing forecasts of the global impact of climate change on economic performance utilising several Atmosphere-Oceanic General

Circulation Models (GCMs) and the Global Impact Model (GIMs). GCMs and GIMs are widely applied for weather forecasting, understanding the climate, and projecting climate change.The results showed that the impact of climate change will depend on the location of a countryby year 2100.

According to Mendelsohn et al. (2004), mid to high latitudes countries will benefit from warming as they become more productive while those on the sub-tropical and tropical countries will be hurt. Countries in tropical regions rely heavily on the agriculture sectors which are mainly rain fed and use minimum technology exposing them to the vagaries of climate variability.

The study by Mendelsohn et al. (2004) is important to the this current study as it give evidence to the fact the climate change affect countries differently depending on their locations. Zimbabwe lies in the high latitude making it vulnerable to changes in climate according to the above findings.

Criticism of Estimating the Impact of Climate

In the review of the Stern Review on the Economics of Climate Change, Weitzman, (2007) argued that there areuncertainties associated with the measurement of the impacts of climate change. The Stern Review is an economic analysis of climate change that was commissioned by the British Government. The review had advocated for adoption of immediate measures to reduce Green House Gas (GHG) emissions as a way to fight the effect of climate change. The recommendation was based on the low discount rate used in the model that made the benefits outweigh costs of delaying the action. In this regard, Weitzman, (2007) raised some concerns regarding the model'sappropriateness to measure the rate of climate change. Weitzman (2007)raises the ambiguity associated in selecting the appropriate discount rate as well as the best model to estimate its impact on the economy.

The original Stern Review made use of the Integrated Assessment Models (IAM) to come up with their conclusion, these models make use of several assumptions and its specification is questionable hence the criticism by Weitzman, (2007). Some of the assumptions include the choice of the appropriate discount rate. No single interest is universally accepted with different figures producing different results. In addition, the models usually assume a low population growth meaning less GHG emission as well, which might not be true always.

In view of this development, it is difficult to have a consensus on the best method to estimate the impact of climate change agreeable universally.The appropriate model therefore depends on one's capacity to use complex models as well as the purpose of the study.

Conclusion

Basically, studies discussed above sought to determine the impact of climate change though from different angles with others focusing on selected sectors while others focus on aggregate economy. The most common question dominating the existing studies being to determine the extent of the impact of climate change on economic performance currently and in future. Generally, the findings are consistent with the hypothesis that saysthat climate change negatively affects economic growth though the effects are not homogeneous among sectors and/or countries.

What is lacking in macro studies is the failure to capture correctly the rain season in Zimbabwe as well as the failure to fully implement the theory of endogenous growth model in analysing the impact. In addition, most studies focus on agriculture sector neglecting other sectors and complex linkages that exists between different sectors of the economy. This shortcoming makes them less applicable to Zimbabwe through extrapolation for any meaningful analysis.

CHAPTER 3: Empirical Model, Variable Justification and Data Sources

Introduction

The previous chapter presented literature review while this chapter discusses the empirical model to be estimated for the Zimbabwean economyand the implication of the endogenous growth model. It also discusses variable justification and data sources, its limitations and the most appropriate model to achieve the objectives of this study.

Empirical Model for the study

As discussed above the implication of the endogenous growth model is that, factors of production especially labour and human capital become more productive with time. This is achieved through learning by doing and knowledge spillover. This means that, existing factors of production can drive economic growth in the following periods holding all other factors constant. To capture this phenomenon, the model to be estimated in this study will include lagged exogenous variables.

In addition, the rainfall pattern in Zimbabwe overlaps between years. As stated earlier in the background of the study, rainfall seasons starts in October and ends in March the following year. This means that previous rainfall affect production in both current and next year. In view of this, lagged rainfall variable will be included in the model to capture this structure.

Empirical equation

After taking logs and finding the change of the equation 3 presented in the previous chapter under the endogenous growth model, the following equation is derived.

$$\Delta \ln Y = \alpha \Delta \ln K + \beta \Delta \ln L + \chi \Delta \ln H + \delta \Delta \ln C \quad \text{..........4}$$

Equation 4 above, is basically a growth equation, with economic growth being explained by increase in physical capital, labour, human capital and climate. It can be further simplified to become:

$$\dot{Y} = \alpha \dot{K} + \beta \dot{L} + \chi \dot{H} + \delta \dot{C} \quad \text{..........5}$$

Where $\dot{Y}$ is output growth rate, $\dot{C}$ is climate change, $\dot{H}$ is growth in human capital, $\dot{K}$ is growth in capital and $\dot{L}$ is growth in labour.

Empirical Model Specification

In line with equation 5 discussed above, the generic form of the model for the purpose of this study is:

$$y_t = \alpha_0 + \alpha_1 inv_t + \alpha_2 pop_t + \alpha_3 hc_t + \alpha_4 tmp_t + \alpha_5 pr_t + \mu_t \text{ ....6}$$

Where:-

y_t = GDP growth rate; hc_t = human capital; pop_t = population growth; inv_t =investment; tmp_t = temperature; pr_t = precipitationand μ_t [4]=Error term. α_0 is a constant term that was included to capture the fact that even in the absence of the identified independent variables economic growth can be witnessed.

Distributed Lag (DL) Model

For the purpose of this study, the DL model was chosen based on its properties as it is believed to be able to capture the implication of endogenous growth model and the overlapping rainfall pattern in Zimbabwe. The model is applicable if variables are integrated of the same order and non-cointergrated. It captures the impact on the dependent variable for the current period due to past and present changes of exogenous variables. The DL model for this study is specified as follows:-

$$y_t = b_0 + \sum_{i-0}^{n} b_i inv_{t-i} + \sum_{i=0}^{n} \alpha_i pop_{t-i} + \sum_{i=0}^{n} \lambda_i hc_{t-i} + \sum_{i=0}^{n} \phi_i tmp_{t-i} + \sum_{i=0}^{n} \varphi_i pr_{t-i} + \varepsilon_t \text{ ....7}$$

Equation 7 above shows that economic growth is explained by present and previous independent variables which are investment, population growth, human capital, temperature and precipitation. One of the major challenges of this model is the selection of the lag length[5]. In this study, Aike Information Criteria was used to overcome this problem. The other challenge is the possibility of multi-collinearity especially if several lags are included in the model. However, multi-collinearity was found to be negligible in the regression model.

[4]The error term is assumed to have a zero mean, constant variance and no autocorrelation.

[5]The matter is discussed in detail in the next chapter.

Definition, Justification of Variables and Data Sources

Dependant Variable

GDP Growth Rates

Output growth rate is used as the dependent variable in equation 7. The use of output growth rate is derived from growth model theory discussed above. Growth models are basically concerned with overall national production. In addition, it is in line with Akram (2012) and Dell et al. (2008) who did a similar study as discussed before. GDP growth is the most widely used measure of economic growth worldwide. Furthermore, data for GDP growth is readily available.

Against this background, GDP growth rate was used as the dependent variable. Data for the period 1991 to 2011 were obtained from ZIMSTAT the official statistics authority for Zimbabwe. The missing data from 1980 to 1990 was obtained from the World Bank[6].

Explanatory Variables

Change in Capital

Basically, the change in capital is attributed to investment and depreciation. Neoclassical growth theory as well as preceding theories attributed output growth to be driven by investment that is, if it exceeds depreciation. If depreciation exceedsinvestment, growth will decline. Solow-Swan (1956) neoclassical growth model cited high levels of investment as one of the important factors behind high growth experience by developed countries. They also attributed higher steady states achieved by developed countries to high levels of savings. The model emphasised investment in physical capital as the driver of growth.

All other growth models identify capital as one of the necessary factors of production that drives growth. Endogenous growth theory acknowledged the role of investment as important for high growth rates but not sufficient. Investment in this case include investment in human capital in addition to physical capital

In line with theory, this study will include investment in physical capital as one of the exogenous variables in the regression model and a positive sign is expected.In this study, investment was included as proxy of change in capital. In Zimbabwe, it is difficult to get data on capital stock, depreciation and complete set of gross investment making it difficult to

[6] Data was obtained from the following website http://devdata.worldbank.org/query/default.htm

calculate net investment. Against this background, Gross Fixed Capital Formation from World Bank, World Development Indicators (2012) was used as a proxy for net investment.

The short coming of using gross investment is that it may not have been sufficient to cover depreciation yet it will be positive. The impact of this is that, instead of having positive relationship with growth it may have a negative relationship contrary to theory and expectation.

Growth in Labour Force

Labour is one of the important factors of production. The neoclassical theory by Solow Swan (1956) attributes output growth to increase in inputs which are labour and capital. Labour increases usually through population growth in the long term which then drives economic growth. Nevertheless growth in labour will eventually experience diminishing returns as more and more labour is employed with capital fixed.

In addition, if population grows faster than production capacity of the economy real output may fall according to Malthus theory. Malthus hypothesised that population grows geometrically while means of subsistence grows at arithmetic pace, due to limited availability of capital therefore population growth retards growth per capita.

A different school of thought was developed by Kuznets who attributed higher levels of consumption, production and saving to increase in population. The theory argued that higher population growth increases consumption, production and savings hence higher growth rate.

From theory discussed above the effect of population growth on economic growth is not clear depending on the stage of development of a given country. Developing countries are usually characterised by high unemployment such that increase in population is likely to retard growth.

Empirically, Akram (2012) found a negative relationship between population growth and economic growth on Asian countries on the study of climate change and growth discussed earlier. However, Odosulo et al. (2009) found a positive sign between economic and populationgrowth in Africa.

Zimbabwe has been characterised by high unemployment for the greater part of the period understudy such that population growth may negatively affect growth. However, based on theoretical and empirical literature discussed above the sign can either be positive or negative.

To capture labour force in Zimbabwe, population growth for people aged between 15 and 64 was used in line with international definition of labour force. Conceptually, labour is defined as people who are willing to work and have reached the legal age to be able to provide their labour force services. Data was extracted from World Bank, World Development Indicators (2012).

Human Capital

Human capital was identified as one of the omitted important determinant of economic growth in the neo-classical growth model by proponents of endogenous growth model. Romer (1986) attributed the divergence of income per capita between rich and poor countries to initial levels of human capital.

Knowledge spill over was cited as enhancing the technology that drives growth. The argument of the endogenous growth theory is that educated labour force utilise capital and technology efficiently resulting in increasing returns to scale. In addition, there is learning by doing which keeps improving labour productivity driving growth. These developments confirm that technological progress is determined within the system unlike in the neoclassical theory where it is exogenously determined.

From empirical studies, Akram (2012), used secondary enrolment as a proxy of human capital in the regression model. The result was that a positive relation was found between economic growth and human capital. Again, Odosulo et al. (2009) used both primary and secondary education as proxy for human capital. They concluded that long run growth is positively related to human capital.

In this study, human capital as measured by secondary enrolment was included as proxy of human capital. Positive sign is expected between human capital and economic growth.

Healthy, educated and experienced labour force is generally regarded as human capital in endogenous growth theories. There is no index that is readily available that captures all the three components. Therefore, secondary enrolment was used as a proxy for human capital on the rationale that anyone who enrolled at high school is likely to be able to read and write which makes the person more productive than someone who did not. In addition, high school enrolment figures are readily available. Data on secondary enrolment was obtained from World Bank, World Development Indicators (2012).

Climate Change

To test the hypothesis that climate change affects growths, climate variable is added into the model to determine if it is significant. Precipitation and temperature are widely used to represent climate change though there are several other variables such as GHG emission levels, atmospheric GHG concentration levels, sea-level rise and intensity or frequency of extreme events that are also most commonly used as indicators. Climate change manifests itself through increase in theoccurrence and intensity of droughts, flooding, and storm damage among other weather events. This development puts temperature and rainfall on the spotlight.

In addition, precipitation and temperature are usually used due to their readily available data. The variables are also chosen based on their theoretical relationship with climate change. Theoretically, increase in average temperatures is closely associated with increase in (GHG) concentration thereby reducing agricultural yields as well as affecting investments.

Almost all studies discussed above found that a decline in rainfall and increase in temperature is negatively associated with economic growth and the reverse is true. In line with this discussion, temperature and rainfall will be used as proxies of climate change in the regression model. Rainfall and temperature is expected to have a positive and negative sign, respectively.

Precipitation and temperature variables have been used in line with empirical studies discussed in the previous chapter. Data source for these variables is the Meteorology Department.

Conclusion

This chapter has outlined the generic and empirical methodology used in this study. In addition, it has outlined variables used and the source of the data usedin this study. It has laid the foundation for chapter 4, which dealt with the actual estimation within the model outlined above and interpretation of the results. Estimation was done using E-views software, version 7.

CHAPTER 4: Estimation, Presentation and Interpretation of Results

Introduction

This chapter begins by analysing descriptive statistics of the variables used in the study.It also presents the results for the test of correlation between the variables. Stationarity tests preceded the estimation ofDistributed Lag Regression Model and post diagnostic tests. The chapter ends by discussing estimated results from the regression.

Results

Descriptive Statistics

Descriptive statistics of the variableswere undertaken before estimation of the model. They provided information on means, standard deviation, maximum, minima, standard deviation, skewness, kurtosis and Jarque-Bera statisticof all the variables. The analysis was done in order to identify mistakes, observe patterns in the data and to find violations of statistical assumptions. It helped to examine the normality of the data set before estimation was carried out.Normally distributed data produces credible and reliable results in line with the assumptions of Classical Linear Regression Models (CLRM). In addition, the mean of normally distributed data can be treated as true mean of the population. Normally distributed small samples data is critical to be able to use t, F and χ^2 tests.

Table 1: Descriptive Statistics Results

	ENROL	**GDP**	**INV**	**POP**	**RAINFALL**	**TEMP**
Mean	710482.9	1.439063	16.18288	2.246875	632.1438	20.13750
Median	731221.5	1.275000	16.14615	2.300000	647.3500	20.07500
Maximum	1053246.	14.40000	16.42434	3.800000	883.5000	21.20000
Minimum	74746.00	-9.900000	16.01932	0.700000	335.3000	19.25000
Std. Dev.	257939.6	6.269907	0.111313	0.971857	149.2478	0.428614
Skewness	-0.867912	0.172725	0.593944	-0.123458	-0.225607	0.543962
Kurtosis	3.073059	2.279141	2.379081	1.766993	1.971789	3.019075
Jarque-Bera	4.024566	0.851965	2.395493	2.108364	1.681082	1.578589
Probability	0.133683	0.653128	0.301874	0.348477	0.431477	0.454165
Sum	22735453	46.05000	517.8522	71.90000	20228.60	644.4000
Sum Sq. Dev.	2.06E+12	1218.664	0.384110	29.27969	690522.5	5.695000
Observations	32	32	32	32	32	32

Results of descriptive statistics are shown on table 1 above. All the six variables hadJarque-Bera probability statistic of greater than 10%. These results mean that both at 5 and 10%, data is normally distributed. Mean for GDP growth rate stood at 1.44% with standard deviation of

6.28%. Rainfall and temperature have a mean of 634.1mm and 20.1°C and standard deviation of 149mm and 0.43°C, respectively.The mean and median for all variables are close confirming normality of data. This data therefore satisfiesthe Classical Linear Regression requirementsof normality so we proceeded with the regression.

Correlation Analysis

Correlation analysis was carried out between the variables in order to rule out the chances of having multi-collinearity. The correlation analysis measures the degree of co-movement between variables. Variables with correlation of above 80% mean that there is multi-collinearity, one of them have to be dropped.

Table 2 below, presents the correlation matrix for the variables to be included in the regression. From the results, no variables have a correlation of above 80% meaning that they may all be included in the regression.

Table 2: Correlation Analysis

	ENROL	GDP	LINV	RAINFALL	TEMP	POP
ENROL	1					
GDP	-0.426	1				
LINV	-0.035	0.039	1			
RAINFALL	0.3	-0.136	-0.255	1		
TEMP	0.176	-0.267	0.337	-0.048	1	
POP	-0.721	0.457	0.221	-0.325	-0.050	1

The lowest correlation is -0.721 between population growth and enrolment while the highest is 0.337 between investment and temperature. From table 2 above, GDP growth has negative relationship with both temperature and precipitation. Since there is no evidence of multi-collinearity the study proceeded to unit root test.

Stationarity Tests

Time series data is usually associated with non-stationarity. Running a regression with non - stationary variables often result in spurious regression (Fedderke 2003). With non-stationary data, R^2 will be overstated meaning that the model appear to explain well the dependent variable yet there will be no meaningful statistical relationship between the variables. In addition, the coefficients and standard errors will be biased resulting in high t values. The investigation of stationarity or non-stationarity can be referred to as a unit roots tests. A time series is stationary if its mean and variance are independent of time.

There are several methods available to investigate the existence of unit roots with the popular one being the Augmented Dickey Fuller (ADF) tests by Dickey and Fuller (1979). Other tests that can be conducted to test for stationarity of time series variables include Dickey-fuller (DF), Auto-Correlation Function (ACF) and the Phillips-Peron test. The superiority of the ADF comes from its consistency, accuracy and its ability to correct for serial autocorrelation (Perotti, 2004).

Against this background, unit root test were done to determine the stationarity properties of the variables. Augmented Dickey-Fuller test was used for this purpose. The results in table 3 below show that all variables are stationary at 5% and at 1% except GDP growth rate which is not really stationary at 1%. The conclusion is reached after noticing that all the probabilities are below 5% meaning that we reject the null hypothesis that the variables are non-stationary in levels. However, log investment and population growth are stationary in levels only with a trend and intercept.

Table 3:Unit Root Tests Results in levels Using ADF[7]

Variable	t-Statistic	Probability	With Trend and Intercept
GDP	-3.590279	0.0119	No
Enrol	-4.290584	0.002	No
Linv	-4.688875	0.002	Yes
Pop	-4.400917	0.00071	Yes
Rainfall	-5.136990	0.002	No
Temp	-4.670163	0.008	No

As all variables were stationary in levels, so we proceeded to estimate DL model using OLS after determining the lag length.

Lag Length Selection

An important step in estimatingDL framework is the determination of the appropriate number of lags. It is important to carefully choose the number of lags applied to the exogenous variables. If lags are too short, the fullimpact of the model will not be captured. However, estimating too many lags will cause the model to lose some degrees of freedom as greater number of parameters will have to be estimated.

[7]Critical values for ADF are -4.3942, -3.6118 and -3.2418 in levels at 1%, 5% and 10% respectively. Null hypothesis for ADF tests is that the series are non-stationary.

To overcome this inherent weakness in DL, there must be a trade-off between having a satisfactory number of lags and having *n* adequate number of degrees of freedom. This was achieved by using the Schwarz Information Criterion (SIC) and Aike Information Criteria (AIC), which are suitable for relatively smaller samples. Guided by these two methods, a general to specific approach was employed to come up with parsimonious equation. The results of the test are presented in table 3 below.

Table 4: Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-67.00499	NA*	41.10416*	6.545908	6.793873*	6.604321*
1	-66.93865	0.096491	45.01838	6.630787	6.928344	6.700882
2	-66.09039	1.156725	46.04346	6.644581	6.991731	6.726359
3	-66.03139	0.075096	50.76038	6.730126	7.126869	6.823587
4	-63.80845	2.627108	46.15147	6.618950	7.065285	6.724093
5	-62.91198	0.977965	47.57099	6.628362	7.124290	6.745188
6	-60.33783	2.574155	42.35100	6.485257*	7.030778	6.613765
7	-60.04961	0.262010	46.75654	6.549965	7.145079	6.690156
8	-59.52183	0.431824	50.97431	6.592894	7.237600	6.744767
9	-57.76601	1.276958	50.28244	6.524183	7.218483	6.687739
10	-57.73364	0.020600	58.88836	6.612149	7.356042	6.787388

* indicates lag order selected by the criterion

From the table above,the majority are pointing at zero lag but AIC is suggesting a maximum of 6. Against this background, discretion was used to start at lag length of 4 and eliminate non-significant variables to come up with parsimonious equation.

Regressions Results

The DL model was developed taking into account that not all independent variables have a once off effect on exogenous variable as implied by endogenous growth model. The immediate impact of the independent variable is called the short run multiplier because it is only the impact that is transmitted with the rest being felt in following periods and these are called long run multipliers. The sum of all coefficients of the lagged exogenous variables gives the total impact of the variables on dependent variable.

Results are in table 9 attached on the appendix section. They show that almost all variables are insignificant as indicated by probability values which are greater than 5%. R-squared is very high and adjusted R-squared does not make economic sense with a negative sign. In addition, F-statistic probability is close to one meaning the model is highly insignificant. The next step was to reduce the general equationto specific equation through elimination of some insignificant variables.

Parsimonious Regression Results

After removing statistically insignificant variables, results in table 5 below were obtained. The model now has some variables that are statistically significant at 5% and 10% level. Variables are said to be statistically significant when their probability is less than 0.01, 0.05, and 0.1 at 1%, 5% and 10%, respectively. At the same time the model is said to be statistically significant at same levels as above when the F-statistic probability is below the same threshold. In this case, R-squared is about 61% meaning that the model explains around 61% of GDP growth in Zimbabwe. Adjusted R-squared is 43% which is fairly good. Adjusted R-square takes into account the number of parameters estimated.

Table 5: Parsimonious Regression Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ENROL	-4.28E-05	2.16E-05	-1.986027	0.0609
LINV	14.43001	8.466877	1.704290	0.1038
LINV(-2)	-19.24963	8.257951	-2.331042	0.0303
POP	5.552375	1.596766	3.477262	0.0024
POP(-1)	2.090372	2.014648	1.037586	0.3118
POP(-2)	6.497709	2.390429	2.718219	0.0132
RAINFALL(-1)	0.014709	0.008041	1.829218	0.0823
TEMP	3.871949	2.832525	1.366960	0.1868
C	-44.31378	155.9318	-0.284187	0.7792
@TREND	2.189895	0.821118	2.666966	0.0148
R-squared	0.609382	Mean dependent var		0.638333
Adjusted R-squared	0.433604	S.D. dependent var		5.598948
S.E. of regression	4.213729	Akaike info criterion		5.975774
Sum squared resid	355.1102	Schwarz criterion		6.442840
Log likelihood	-79.63662	Hannan-Quinn criter.		6.125193
F-statistic	3.466769	Durbin-Watson stat		2.213709
Prob(F-statistic)	0.009857			

F- statistic probability is 0.0099 which is less than 1% meaning that the whole model is significant at 1%.Before analysing these results, post regression diagnosis were carried out to check for auto-correlation, heteroscedasticity, serial correlationand normality.

Post Regression Diagnostics

To make the model robust, the CLRM assumptions require that the error term be normally distributed, there be no serial correlation and the error term be homoskedastic. These requirements emanate from the fact that most regressions are done from samples in order to draw inferences about the population regression function. For the estimated regression to be able to be used with confidence it should satisfy the assumptions of CLRM.

Normality Test

The CLRM assumptions requires that error terms from the regression be normally distributed.The normality assumption requires that a mean of the error term be zero and the variance be constant which can be written in short as follows:-

ui ~ N(0, σ2)

where the symbol ~ means distributed as and N stands for the normal distribution, the terms in the parentheses representing the two parameters of the normal distribution, which are the mean and the variance (Gujarati 1995). This requirement means that the effect of the omitted variables on the dependent variables be small and random. To test for normality of the error terms, Jarque-Bera (JB) test statisticwas usedthough other methods such as histogram of residuals are also available. In this study, JB statistic test was employed and it can be written as follows:-

$$JB = n\left[\frac{s^2}{6} + \frac{(k-3)^2}{24}\right]$$

Where n is the population size, s if the skewness co-efficient and k is the kurtosis co-efficient. The null hypothesis is that the residuals are normally distributed. However, the method is not applicable when the sample is too small.From the test, Jarque-Bera statistic for normality test had a P value of 0.83 suggesting normal distribution of the residuals. Tests results are shown in fugure 3 in the appendix.

Homoscedasticitic Test

Another important diagnostic test is the test for the presence of heteroscedasticity.Homoscedasticity means that that variance of error term is constant and if otherwise the variance of the parameters is not minimum meaning that the variances of the coefficients are not efficient. The effect of heteroscedasticity is that the confidence interval and hypothesis testing will be inaccurate. There are several methods available to test the presence of heteroscedasticity but this study employed Autoregressive Conditional Heteroscedasticity-Langrange Multiplier (ARCH-LM) test.From results, we do not reject that the model is homoskedastic using ARCH test which has an observed R-squared, Probability Chi-squared of 34% as shown in table 9 attached to the appendix.

Autocorrelation Test

Autocorrelation is common in time series data. Its presence results in the disturbance term being influenced by another error term associated with a different observation. Autocorrelation makes interval and hypothesis test inaccurate. In this study, higher order serial correlation was tested using the Breusch-Godfrey test. Its advantage is that it allows the inclusion of lagged variables in the model unlike other tests like Durbin-Watson test.

From the diagnostic results we do not reject the null hypothesis that there is no serial correlation using the Breusch-Godfrey LM test since observed R-squared,Probability Chi-squared is 0.58 which is way above 0.05 as shown in table 8 attached to the appendix.

The post regression diagnostic results discussed above show that the model can be used to infer the findings of the study.

Explanation of Results(*Table 5*)
Human capital as proxied by secondary enrolment is statisticallysignificant at 10% with a negative sign. An increase of enrolment by 1 000 students, results in GDP growth of -12.13%. This result is contrary to endogenous growth theory which attributes sustained growth to human capital. This outcome can be explained bythe fact that, secondary enrolment in Zimbabwe has been systematically going up during the period covered by this study. However, economic growth has been in the negative territory if outliers of 1980 and 2011 are removed. The reason for slow growth can be attributed to other problems such as poor or weak institutions. Corruption, political instability and low enforcement of property rights characterised the period under study resulting in failure of the economy to benefit from increase in enrolment. Human capital is not sufficient condition for growth because other factors have to be in place as well.

Investment has a positive effect on GDP growth, however, its significance probability ismarginally above the 10% threshold.The sign is consistent with growth theories that investment is one of the major drivers of growth. The statistically insignificance of investment maybe attributed to the fact that the investment figuresused in this study are gross so that the greater part maybe was for covering depreciation only. If that is the case investment may apper to negatively affect economic growth. However, two year lagged investment is significant at 5% with negative sign which is contradictory to theory. We would expect investment to stimulate growth at least in the current period with major impact being felt in subsequent years. The negative sign can be explained again by the gross investment figure which might not be able to cover depreciation. In situation like this investment will be associated with low growth as capital become less productive with time.

Labour as measured by population growth for the age 15 to 64 years is statistically significant for the current period and the previous two periods. Population growth is statistically significant in the current period at 5% level with a positive sign. Growth of population by 1% in the current period will result in 5.5% growth in GDP. Population growth in previous two years is statistically significant at 5% with a positive sign. Growth of 1% of labour force in the previous two results in 6.5% GDP growth in the current year. This outcome is in line with endogenous growth model where itis hypothesised that labour productivity increaseswith time through learning by doing. This means that as labour acquire experience it will be able to produce even more with the same technology.

Rainfall is statistically significant at 10% with a positive sign. An increase of rainfall by 100 mm in the previous year results in 0.015% GDP growth in the current year.Considering that the sample size is small, significance at 10% is acceptable to draw some conclusion from the regression. The results are similar to the one found by Akram (2012) that rainfall positively affects GDP growth. However, in Akram (2012) current rainfall variable was the one that was used while in this study previous year's rainfall was the one found to have an effect on current growth. The explanation to this difference can be due to differences in rainfall season. In Zimbabwe, rainfall season stretches from October to March in the following year. This means that previous year's rainfall determines the economic activity in the following year. The explanation is plausible in that, if there is no rainfall in the previous year then economic activity in the next period will be subdued. The results showed that climate change has minimal negative effect on economic growth in Zimbabwe.

Temperature has a positive sign butstatistically insignificant even at 10%. Though statistically insignificant the sign is contrary to what is generally expected and to other studies by Akram (2012), Odosulo et al (2009) and Dell at al (2008) who found a negative relationship and significant relationship.Since temperature variable is statistically insignificant means that changes in temperature brought by climate change has minimum effect on economic growth in Zimbabwe. This can be attributed to the agro type of economy that characterise Zimbabwe. Agriculture production mainly requires rainfall and temperature is a less important variable.

From the results, rainfall affects economic growth more than temperature. This is evidenced by the statistically insignificance of temperature while rainfall is significant at 10%. In addition, temperature has a positive sign meaning that increases in temperature even drive growth in Zimbabwe though it is insignificant. Furthermore, from Wald test shown in table 10 in the appendix, we reject the null hypothesis that a coefficient of rainfall is equal to the coefficient of temperature. The Wald test was done to determine the importance of individual coefficients of rainfall and temperature.

Conclusion

This chapter presented the results from the diagnosisandeconometric regression carried out in this study.The results showed that investment, labour and rainfall are some of the drivers of growth in Zimbabwe, however,enrolment proves to be negatively affecting growth. Climate change proxied by temperature and rainfall appear to have minimum effect in explaining growth in Zimbabwe. The model used in this study appear to fairly explain growth drivers in Zimbabwe as evidenced by moderate R-squared.The following chapter looks at the conclusion and policy implications.

CHAPTER 5: Conclusions and Recommendations

Introduction

This chapter presents the summary and conclusions for the study based on the results obtained in chapter four. The chapter also discusses implications of the results to different stakeholders that include policy makers and implementers. In addition, the chapter highlights possible areas which need further research.

Conclusions

This study sought to determine the role of climate change on economic growth in Zimbabwe for the period 1980-2011. To achieve this, climate variables were incorporated in the endogenous growth model.The Distributed Lag model was used as the empirical model to capture the implications of the endogenous growth model and the overlapping rainfall season in Zimbabwe.

The results point to a positive relationship between GDP growth and rainfall. This relationship means that more rainfall is favourable to drive growth in Zimbabwe. The results are consistent with the hypothesis that rainfall has a positive relationship with GDP growth. However, historical rainfall data points to declining trend as well as increase in variability partly due to climate change. This development poses a challenge to Zimbabwe's economic performance as it negatively affects growth.

Results also show that temperature has no statistical relationship with GDP growth in Zimbabwe which is generally against the proposition that it has a negative relationship. This finding is also contrary to other empirical findings by Dell et al (2008) and others who found a significant and negative relationship.

Considering that rainfall was statistically significant and temperature was not, this may be evident that rainfall variability is the major threat to economic growth in Zimbabwe than temperature increase. Overally, the results mean that climate change is not a major challenge to growth in Zimbabwe. The study also found that investment, population growth and human capital are some of the drivers of economic growth in Zimbabwe.

Policy Recommendation

Based on the results discussed above, climate change is not a serious challenge as being presumed by some stakeholders though it remains something to be wary of, in Zimbabwe. Nevertheless policy makers are advised to pursue alternative sources of water instead of relying on rainfall which has become erratic. Some of the alternative source of water includesdams and underground water for irrigation and industrial supplies. Water is the engine of all economic activities especially agriculture. This is even more important given that Zimbabwe is an agriculture driven economy.

Construction of dams may be very expensive and long term goal but in the mean time policy makers should facilitate the promotion of short term and drought resistant crops to ensure that agriculture production is not severely affected by rainfall variation. Instead of growing maize, small grains that are drought resistant can be grown by farmers in most regions and not only in natural Region 5.Another long term solution is to develop the economy such that it ceases to be agriculture depended.

Suggestion for Future Studies

The results found in this study are not consistent with other studies done on other countries which found severe impact of climate change on economic `growth. The results call for further studies in this area so that categorical results can be reached for Zimbabwe. There is need to carry other studies using various methodology such as CGE models and others, to see if the results will be the same. This study used a simple Distributed Lag Model due to time and data constraints which if sophisticated models are used that could improve the results from the same study.

Zimbabwe is comprised of different regions with different climate conditions such that the impact can be different from one region to another. Against this background, there is need to carry out sub-national studies to determine regions which are more vulnerable and proffer policy advise accordingly.

BIBLIOGRAPHY

Acock,B. and Allen, L. H. (1985). Crop responses to elevated carbon dioxide concentrations. In: Strain BR. Cure JD (eds) *Direct effects of increasing carbon dioxide on vegetation*. U S. Department of Energy, Washington, DC, p 33-97

Akram, N. (2012). Is climate change hindering economic growth of Asian economies?. *Asia-Pacific Development Journal* Vol. 19, No. 2.

Antle, J. M.(1995). Climate change and agriculture in developing countries. *American Journal of Agricultural Economics* 77: 741-746.

Barro, R. (1991). Economic Growth in a Cross Section of Countries.*Quarterly Journal of Economics*, 106, 407-43.

Barro, R. (1989). Economic Growth in a Cross Section of Countries. Working Paper No. 3120. National Bureau of Economic Reaserch. Cambridge.

Biemans, H. Bresser, T., Van, S. H. and Kabat, P. (2006). Water and Climate Risks: A plea for climate proofing of water development strategies and measurers. Co-operative programme on Water and Climate, Delft, 35 pp.

Bigano, A., Bosello. F., Roson, R. and Tol. R. S. J. (2006). Economy-Wide Estimates of the Implications of Climate Change: A Joint Analysis for Sea Level Rise and Tourism. Fondazione Eni Enrico Mattei.

Chagutah, T. (2010). 'Climate Change Vulnerability and Adaptation Preparedness in Southern Africa: Zimbabwe Country'. Heinrich Böll Stiftung Southern Africa (HBS).

Climate Handbook of Zimbabwe (1981). Department of MeteorologicalServices, Harare

Cline, W.R. (1994). The costs and benefits of greenhouse gas abatement. A guide to policy analysis. In the Economics of Climate Change. Paris: OECD.

Cline, W. R.(1996). The impact of global warming on agriculture: Comment. *American Economic Review* 86: 1309–12.

Davis, A and Sadiq, I. (2010). Effect of Climate Change on Cocoa Yield: a Case of Cocoa Research Institute (CRIN) Farm, Oluyole Local Government Ibadan Oyo State. *Journal of Sustainable Development in Africa* (Volume 12, No.1, 2010). Clarion University of Pennsylvania, Clarion, Pennsylvania.

Dell, Melissa, Benjamin, F. J, and Benjamin, A. O., (2008). "Temperature Shocks and Economic Growth: Evidence from the Last Half Century." *American Economic Journal: Macroeconomics* 4.3 (2012): 66–95.

Deressa, T. T. (2007). Measuring The Economic Impact of Climate Change on Ethiopian Agriculture: Ricardian Approach. The World Bank Development. Research Group Sustainable Rural and Urban Development Team.

Dickey and Fuller, (1979). Distribution of the Estimators for Autoregressive Time Series with a Unit Root. *Journal of American Statistical Association*, 74: p427-431.

Elshennaway, A., Robinson, S. and Willenbockel, D. (2013). Climate Change and Economic Growth: An Intertemporal General EquilibriumAnalysis for Egypt. American University Cairo, International Food Policy Research Institute, Institute of Development Studies at the University of Sussex.

Ekbom, A. and Dahlberg, E. (2008). Economic Growth, Environment and Climate Change. Environment Economics Unit. University of Gothenburg.

Enders, W. (2003). Applied Econometric Time Series. New York: John Wiley and Sons.

Engle, R.F and Granger, C.W.J. (1987). Co-Integration and Error Correction: Representation, Estimation and Testing. *Econometrica*, 55(2), 251-276.

Eriksen, S., O'Brien, K. and Rosentrater, L. (2008). Climate Change in Eastern and Sourthen Africa: Impacts, Vulnerability and Adaptation. Department of Sociology and Human Geography. University of Oslo.

Fazal, S. A. & Wahab, (2013). Economic Impact of Climate Change on Agricultural Sector: *A Review* Vol. 1, Issue 1, pp: 39-49. Universiti Malaysia, Kelantan.

Fedderke, J. (2003). Applied Time Series Analysis. University of Cape Town. South Africa.

Frost, P. G. H. (2001). Zimbabwe and United Nations Framework Convention on Climate Change. Working Paper. Institute of Environmental Studies, University of Zimbabwe.

Godfray, H. Charles, John R. Beddington, Ian R. Crute, Lawerence, H., David,L., James, F., Muor, Jules, P., Sherman, R., Sandy, M. Thomas and Camilla, T. (2010). Food Security: *The Challenge of Feeding 9 Billion People.*Science 327, 812.

Green, W. H. (2002). Econometric Analysis. Fifth Edition. New York University.

Gross, J. (2002). The Severe Impact of Climate Change on Developing Countries. Medicine and Global Survival.

Gujarati, D.N. (1995).Basic Econometrics, 3rd Ed. McGraw-Hill International edition.

Gwimbi, P. and Mundoga, T. (2010). Impact of climate change on cotton production under rainfed conditions: case of Gokwe.*Journal of Sustainable Development in Africa*. Vol 12, No.8.

Hulme and Mike, ed. (1996). Climate Change and Southern Africa. Norwich, United Kingdom: Climatic Research Unit, University of East Anglia.

Hsiang and Solomon, M. (2010). Temperatures and Cyclones Strongly Associated with Economic Production in the Caribbean and Central America. *Proceedings of the National Academy of Sciences* 107, 15367-15372.

Jain, (2006). Climate Change and African Agriculture: The Economic Impacts of Climate Change on Agriculture in Zambia. CEEPA Discussion Paper No. 27, CEEPA, University of Pretoria.

Jayaraman, T. (2011). “Climate change and Agriculture: A Review Article with Special Reference to India”, *The Journal of the Foundation for Agrarian Studies*, Vol. 1, No.2.

Jones, C. A. Kiniry, T. (eds) (1986). CERES-Maize: a simulation model of maize growth and development. Texas A&M University Press, College Statlon.

Kimengsi, J. N. and Tosam, N. J. (2013). Climate Variabilityand Cocoa Productionin Meme Division ofCameroon:AgriculturalDevelopment Policyoptions. *Greener Journal of Agriculture Science*, Vol 3(8), pp 606-617.

Kurukulasuriya, P. and Rosenthal, S. (2003). Climate Change and Agriculture: A Review of Impacts and Adaptation. The International Bank for Reconstruction and Development/THE WORLD BANK Washington, D.C., U.S.A.

Levine, R. and Renelt, D. (1992), A Sensitivity Analysis of Cross-Country Growth Regressions, *American Economic Review*, 82, 942-63.

Makadho, J.M. (1996). Potential Effects of Climate Change on Corn Production in Zimbabwe. *Climate Research 6:147-151*.

Mano, R. and Nhemachena, C.(2007). ‘Assessment of the Economic Impacts of Climate Change on Agriculture in Zimbabwe: A Ricardian Approach’ CEEPA discussion paper 11.

Mendelsohn, R. (2000). Measuring the effect of Climate Change on Developing Country Agriculture. Two essays on climate change and agriculture: A developing country perspective. FAO Economic and Social Development Paper 145.

Mendelsohn, R. Dinar, A. and Dalfelt, A. (2000). Climate Change Impacts on African Agriculture. World Bank.

Mendelsohn, R.& Dinar, A. (2003). Climate, Water and Agriculture:*Land Economics* 79(3):328–341.

Mendelsohn, R. Dinar, A. and Sanghi, A. (2001). The Effect of Development on the Climate Sensitivity of Agriculture. Environment and Development Economics. Cambridge University Press.

Mendelsohn, R., Nordhaus, W. and Shaw, D.(1994). The impact of global warming on agriculture: A Ricardian analysis. *American Economic Review* 84: 753–771.

Mendelsohn, R., and Williams,L. (2004). Comparing forecasts of the Global Impacts of Climate Change. *Mitigation and Adaptation Strategies for Global Change*, vol. 9, No.4 , pp. 315-333.

Muller, C., Cramer, W., Hare, W. L. and Lotze-Campen, H. (2011). Climate Change Risks for Africa Agriculture. Earth System Analysis, Potsdam Institute for Climate Impact Research, Potsdam, Germany.

Mutasa, C.(2008). Evidence of Climate Change in Zimbabwe. Paper presented at the Climate Change Awareness and Dialogue Workshop for Mashonaland Central and Mashonaland West Provinces Held at Caribbea Bay Hotel, Kariba, Zimbabwe, 29-30 September, 2008.

Ngaira, J. K. W. (2007). Impact of Climate Change on Agriculture in Africa by 2030. School of Environment and Earth Sciences. Maseno University, Kenya.

Nhemachena, R. and Hasan, R. (2007). Micro-Level Analysis of Farmers' Adaptation to Climate Change in Southern Africa. IFPRI Discussion Paper 00714. Environment and Production Technology Division. Washington, DC .USA.

Nordhaus, W.D. (1991). "To slow or not to slow: the economics of the greenhouse effect", *Economic Journal*, 101.

Intergovernmental Panel on Climate Change (2001). IPCCFourth Assessment Report, Working Groups I, II, and III.

Intergovernmental Panel on Climate (2007).Change Climate Change: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, New York, NY.

Odosulo,A. F. and Abidoye, B. O. (2009). Climate Change and Economic Growth in Africa: An Econometric Analysis. United Nations Development Programme. University of Pretoria.

Ouedraogo, M., Some, L. and Dembele, Y. (2006). Economic Impact Assessment of Climate Change on Agriculture in Burkina Faso: A Ricardian Approach. Centre for Environmental Economics and Policy in Africa (CEEPA), Pretoria, South Africa.

Pittock, A. B. Salinger, M. J. (1991). Southern Hemisphere climate scenarios. *Climate Change* 18:205-222.

Polsky, C.(2004). Putting space and time in Ricardian Climate Change Impact Studies:Agriculture in the US Great Plains, 1969–1992. *Annals of the Association of American Geographers* 94(3): 549–564.

Romer, P. M. (1987). "Growth Based on Increasing Returns Due to Specialization," American Economic Review.

Roson, R. (2003). Modelling the Economic Impact of Climate Change. EEE Working Papers Series - N. 9. University of Venice, Italy.

Sala-i-Martin, X. (1997), ‘I Just Ran 2 Million Regressions’, American Economic Review.

Seo, S. and Mendelsohn, R., (2006). The Impact of Climate Change on Livestock Management in Africa: a structural Ricardian analysis. CEEPA Discussion Paper No. 23, Centre for Environmental Economics and Policy in Africa, University of Pretoria.

Sivakumar, M. V. K. (2006). Climate Prediction and Agriculture: Current Status and Future Challenges. World Meteorological Organisation. Geneva, Switzerland.

Thurlow, J., Zhu, T.and Diao, X. (2009): "The Impact of Climate Variability and Change on Economic Growth and Poverty in Zambia". IFPRI Discussion Paper 00890, Washington, DC: International Food Policy Research Institute. University of Maryland.

Tol, R.S.J. (1995). The damage costs of climate change toward more comprehensive calculations. *Environmental and Resource Economics*, vol. 5, No. 4, pp. 353-374.

Tucker, G. B. (1991). Confidence in modelling future climate: a Southern Hemisphere perspective. *Climate Change* 18:195-204.

United Nations Framework Convention on Climate Change(UNFCCC), (1992). the convention document.

Unganai, L. S. (1996). 'Historic and future climatic change in Zimbabwe' *Climate Research* Vol 6, 137-145.

United State Census Bureau Wold Projection (2012). Downloaded from: https://www.census.gov/popclock/ on January 27, 2014.

Weitzman, M. (2007). A review of the Stern Review on the Economics of Climate Change. *Journal of Economic Literature*, vol. XLV, pp. 703-724.

World Bank, (2012). World Development Indicators

Wright, J. C. (1993). Banana and Plantain, AB International Wallongfood.

APPENDIX

Table 6: Data used in the Study

obs	GDP Growth Rates	ENROL	LINV	POP Growth rates	RAINFALL (mm)	TEMP (℃)
1980	14.4	74746	16.05822589	2.6	860.7	19.6
1981	12.5	149018	16.14367494	3.1	439.7	19.25
1982	2.6	227613	16.23144465	3.5	403.1	19.95
1983	1.6	316435	16.14658903	3.3	464	20.85
1984	-1.9	416413	16.17612477	3.6	745.9	19.65
1985	6.9	482000	16.08488115	3.8	695.4	19.7
1986	2.1	537348	16.12439409	3.1	422.4	19.65
1987	1.15	604188	16.14572026	3.6	744	20.8
1988	7.6	640668	16.2465121	3.4	605.3	20.05
1989	5.2	670266	16.24659112	3.2	625.1	20
1990	0	661066	16.30000879	2.4	501.6	20.4
1991	5.5	710619	16.33620125	2.9	335.3	20.5
1992	-7	657344	16.04027242	2.3	629.7	21.2
1993	2.1	639559	16.36881223	2.1	519.2	20.25
1994	5.8	660986	16.25476674	3	418.8	20.05
1995	0.2	711094	16.34942283	1.8	700.5	20.85
1996	9.69	751349	16.11107497	2.3	801.6	20.1
1997	1.4	806126	16.42433826	2.8	532	20.65
1998	0.5	847296	16.39988125	1.5	778.9	20.7
1999	-3.6	859741	16.15734349	1.7	883.5	20.1
2000	-8.19	863012	16.29737823	2	728.6	19.85
2001	-0.2	870241	16.1371406	0.9	465.7	20.3
2002	-5.9	875142	16.11337179	2.4	602	19.9
2003	-7.5	885784	16.18748757	1.3	712.3	19.9
2004	-3.6	912689	16.09202207	0.8	529	20.1
2005	-4.09	895194	16.20419021	1.2	835.7	20.1
2006	-3.6	908365	16.01932389	0.7	598.4	19.85
2007	-3.3	987135	16.07714602	0.9	796.2	20.3
2008	-9.9	998395	16.02480807	0.8	734.4	19.9
2009	5.40	1019851	16.11037645	0.9	709.1	19.9
2010	9.6	1042524	16.11626282	1.8	745.4	20.1
2011	10.6	1053246	16.12643207	2.2	665	19.9

Table 7: DL Results with Maximum Lags

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ENROL	8.41E-05	0.000292	0.288032	0.8215
ENROL(-1)	-0.000360	0.000740	-0.485554	0.7122
ENROL(-2)	0.000589	0.000835	0.705883	0.6087
ENROL(-3)	-0.000318	0.000645	-0.492734	0.7085
ENROL(-4)	0.000182	0.000413	0.440923	0.7356
LINV	-34.38522	118.4025	-0.290410	0.8201
LINV(-1)	82.60260	97.01638	0.851429	0.5510
LINV(-2)	-29.74437	59.94605	-0.496186	0.7068
LINV(-3)	-10.52478	41.65826	-0.252646	0.8425
LINV(-4)	2.392187	35.68342	0.067039	0.9574
POP	12.15881	9.901147	1.228020	0.4351
POP(-1)	1.711386	11.41808	0.149884	0.9053
POP(-2)	-15.25321	20.87671	-0.730633	0.5983
POP(-3)	-11.92904	25.74349	-0.463381	0.7238
POP(-4)	-21.61070	31.21369	-0.692347	0.6145
RAINFALL	0.032487	0.050353	0.645188	0.6352
RAINFALL(-1)	0.047876	0.059354	0.806628	0.5679
RAINFALL(-2)	0.021386	0.076571	0.279294	0.8266
RAINFALL(-3)	-0.035368	0.044620	-0.792636	0.5733
RAINFALL(-4)	-0.008835	0.045941	-0.192322	0.8790
TEMP	13.00485	25.91514	0.501824	0.7039
TEMP(-1)	-1.381034	16.52447	-0.083575	0.9469
TEMP(-2)	-21.69251	25.87438	-0.838378	0.5558
TEMP(-3)	-0.263695	16.67489	-0.015814	0.9899
TEMP(-4)	-8.704675	26.41894	-0.329486	0.7974
C	296.9782	877.0559	0.338608	0.7921
@TREND	-8.902268	11.58894	-0.768169	0.5830
R-squared	0.889603	Mean dependent var		0.533929
Adjusted R-squared	-1.980707	S.D. dependent var		5.786383
S.E. of regression	9.990031	Akaike info criterion		6.037419
Sum squared resid	99.80071	Schwarz criterion		7.322045
Log likelihood	-57.52387	Hannan-Quinn criter.		6.430142
F-statistic	0.309933	Durbin-Watson stat		2.915435
Prob(F-statistic)	0.915915			

Table 8: Test for Serial Correlation

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.338649	Prob. F(2,18)	0.7172
Obs*R-squared	1.087895	Prob. Chi-Square(2)	0.5805

H_0: There is no serial correlation

Reject H_0 if $p \leq 0.05$

Test for HeteroskedasciticityARCH LM Test (nR^2)

This test is the autoregressive conditional Heteroscedasticity which tests if the residuals have an ARCH structure at the 5% significant level.

- Belongs to the class of asymptotic, Langrange multiplier test (LM).
- This specification is motivated by the observation that many time series, magnitude of residuals appeared to be related to magnitude of different residuals.
- Test based on the auxiliary regression:

$e^2_t = \beta_o + \beta_1 e^2_{t-1} + \beta_2 e^2_{t-2} + \beta_q e^2_{t-q} + V_t$

H_0: No ARCH up to lag q in residuals $nR^2 \sim \chi^2$ (q), Reject H_0 if $p \leq 0.0$

Table 9: Heteroskedasciticity Results

Heteroskedasticity Test: ARCH			
F-statistic	0.869976	Prob. F(1,27)	0.3592
Obs*R-squared	0.905250	Prob. Chi-Square(1)	0.3414

Test for Normality

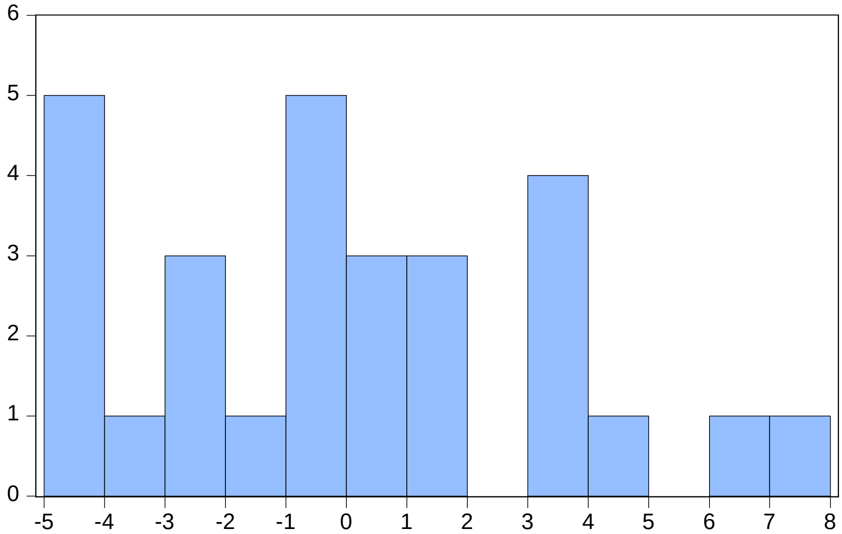
Tested using the Jarque-Bera test statistic.

H_0: Residuals are normally distributed

JB is distributed as χ^2 with two degrees of freedom, i.e. JB~ χ^2

Reject H_0 if $p \leq 0.05$

Figure 3: Results for Normality Test



Series: Residuals	
Sample 1984 2011	
Observations 28	
Mean	0.004542
Median	-0.311694
Maximum	7.291794
Minimum	-4.576811
Std. Dev.	3.313742
Skewness	0.386899
Kurtosis	2.347877
Jarque-Bera	1.194698
Probability	0.550268

Table 10: Wald Test

H_0: Coefficient of temperature is equal to Coefficient of rainfall

Reject H_0 if $p \leq 0.05$

Wald Test:			
Equation: EQ02			
Test Statistic	Value	df	Probability
t-statistic	-1.05204056063351	19	0.3059777060390289
F-statistic	1.10678934121807	(1, 19)	0.3059777060390282
Chi-square	1.10678934121807	1	0.2927809408547284
Null Hypothesis: C(8)=C(6)			
Null Hypothesis Summary:			
Normalized Restriction (= 0)		Value	Std. Err.
Restrictions are linear in coefficients.			