DEPARTMENT OF ECONOMICS

AN ECONOMETRIC ANALYSIS OF THE IMPACT OF CLIMATE CHANGE ON COMMERCIAL BEEF PRODUCTION IN BOTSWANA FROM 1980-2016

BY

ANGELA LESEGO SEOKE

MAIN SUPERVISOR: MR RATHEDI

CO-SUPERVISOR: MS OAGENG

A DISSERTATION SUBMITTED TO THE DEPARTMENT OF ECONOMICS IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE MASTERS OF ARTS (ECONOMICS) DEGREE

MAY 2019

DECLARATION

I hereby declare that this dissertation titled: "*An econometric analysis of the impact of climate change on commercial beef production in Botswana from 1980-2016*" is my own work and sources that have been used are acknowledged by means of complete references. The work submitted is the result of my own investigation and is original.

Name ………………………………………….

Signature …………………………………………..

Date ………………………………………….

Contact details

Telephone: (+267) 74497645

Email: angelalesegoseoke@yahoo.com

APPROVAL

This dissertation has been examined and approved as meeting the requirements for the partial fulfillment of the Master of Arts (Economics) degree.

……………………………

Mr Rathedi

(Supervisor)

Date: …………………………….

..……………………………

Dr. M. Bakwena

(Head of Department)

Date: ……………………………

DEDICATION

To my father Abraham Seoke, my mother Esther Seoke, my sister Neo Seoke, my fiancé Moses Mogaekwa and our son Ryan Seoke.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

ADF – Augmented Dickey Fuller

BOB – Bank of Botswana

CDM – Cold Dressing Mass

CEDA – Citizen Entrepreneurship Development Agency

CGE - Computable General Equilibrium

CO_2 - Carbon dioxide

EU – European Union

FAO – Food and Agriculture Organization

FAP - Financial Assistance Policy

FMD – Foot and Mouth Disease

GDP – Gross Domestic Product

GOB – Government of Botswana

IPCC – Intergovernmental Panel on Climate Change

LIMID - Livestock Management and Infrastructure Development

NPAD - National Policy on Agricultural Development

TGLP - Tribal Grazing Lands Policy

VAR – Vector Autoregressive Model

VECM – Vector Error Correction Model

ACKNOWLEDGEMENTS

I would like to extend my deepest gratitude to my first supervisors Mr Rathedi and Dr P. Makepe and my second supervisor Ms Oageng for the guidance they gave me through the challenges I encountered during the study. I appreciate your assistance a great deal.

I would also like to extend my gratitude to Prof Sinha who assisted me with the econometric analysis of my data on the Eviews software. Sincere thank you to my MA Economics colleagues especially Senzeni Mbanjwa who assisted me in my study it has not been an easy road and I am deeply grateful for all of you who kept me going even when I felt I could not see the light at the end of the tunnel. I also thank all other lecturers and administrative staff in the Department of Economics, University of Botswana for contributing immensely to my success.

Many thanks to the following organizations for providing the needed data for the study: the Department of Meteorological Services, the Botswana Meat Commission (BMC) and the Ministry of Agriculture. A special thank you to Mrs Esther Phiri-King and Mrs Mariam Nkomo at the Department of Meteorological services for your warm welcome and your timely efforts in providing me with all the data I needed and Mr Ngwingwa and Mr Palai and all the wonderful staff members in the livestock department at BMC thank you for your assistance.

Last but not least, a very special and heartfelt thank you to my amazing fiancé Moses Mogaekwa, our beautiful son Ryan and to our amazing parents and siblings who have supported me in my studies. Without all your sacrifices, love and support I would not have achieved my dreams. To my amazing neighbour Mpho Mokgatla thank you so much for all your support and assistance with caring for our son when I needed to work on my research project. Thank God for being my source of strength and guidance throughout my studies. It is all because of him that I was able to complete my dissertation.

ABSTRACT

This study examined the impact of climate change on commercial beef production in Botswana using time series data from 1980-2016. We estimated a Ricardian model to quantify the impact of climate change on commercial beef production in a period of 36 years. The climate change variables used were temperature, rainfall and drought (dummy) and the non-climate change factors used in the model were beef producer prices and the outbreaks of diseases (Foot and Mouth Disease). We found that increasing temperature and rainfall have a significant effect on commercial beef production in Botswana. Drought also had a positive and significant impact on beef production which was unexpected. Beef producer prices were positive and significant and the outbreaks of diseases (Foot and Mouth Disease) were insignificant which was unexpected. , the error correction term coefficient of the average growth rate of beef production (LBP) has a corrective negative sign and is significant. We tested the models for unit root, cointegration and because there was cointegration analysis went further to estimate a Vector Error Correction Model (VECM). The results of the VECM showed that a significant error term implies a disequilibrium adjustment of each variable towards its long run equilibrium value. A significant error term provides validation of the existence of a long run relationship between the variables and speed of adjustment is 0.5 percent. The results all point at the need for raising farmer's awareness of long term climate change and using the appropriate adaptation options to counter the likely adverse impact on commercial beef production.

CHAPTER 1: INTRODUCTION

1.1 Background of the study

Climate change is a change in usual weather patterns of an area observed over a long period, which is attributed directly or indirectly to human activity. This results in modification in the composition of the global atmosphere and is in addition to natural climate variability (IPCC, 2007). According to FAO (2008) increases in human activities and increases in the use of fossil fuels have led to the intensification of greenhouse gas emissions. A rise in atmospheric concentrations of greenhouse gases are likely to result in amplified global warming, and the resulting climate change may threaten the livelihoods of most populations especially those who are dependent on natural resources for survival (Nordhaus, 2003).

Impacts of global climate change include increased: global temperature, erratic rainfall patterns, wild fires, prolonged drought, and frequent flooding. Climate change is likely to have different effects on different sectors of the economy and affect global food supply and heavily impact on livestock and mixed (crop and livestock) subsector systems (Thornton, 2010).

The most vulnerable sectors are agriculture and forestry (IPCC, 2007). Climate change affects the agricultural sector through declining food quantity and quality, worsening the food insecurity in some developing countries. Extreme weather events such as storms, floods and drought affect the productivity of crops and livestock. These also in turn affect food prices (increasing food prices) as there will be a high demand for food but the supply will be low. Agriculture can also contribute to climate change through greenhouse gas emissions and land use effects such as deforestation, as carbon dioxide is released to the atmosphere and through releases of Nitrous oxide from fertilizer use and methane from livestock particularly beef cattle (Adugna, 2016).

Livestock is impacted by climate change indirectly through the quantity and quality of feed produced on grasslands and directly from the effects of higher temperatures (Adams, 1998). Higher temperatures increase incidences of heat stress in livestock, outbreaks of livestock diseases and lead to suppression of livestock appetite reducing their levels of productivity and reproduction (IPCC, 2007; Thornton & Herrero, 2008). This consequently results in loss of income in rural populations who mainly depend on livestock, thus worsening the poverty levels in countries (Thornton & Herrero, 2008) .

It should be noted that animals also contribute to emissions of greenhouse gases (GHGs) (Fereja, 2016). Livestock activities are estimated to contribute about 18% to total GHG (carbon dioxide, methane and nitrous oxide) emissions (Steinfeld, 2006), and 80% of all the emissions is from the agriculture sector. Methane emissions from African cattle, goats and sheep were estimated to likely to increase from about 7.8 million tonnes per year in 2000 to 11.1 million tonnes per year by 2030, mostly driven by increases in livestock numbers (Thornton & Herrero, 2008). In this study our emphasis is on the impacts of climate change on livestock production with emphasis on beef production.

Agriculture was the backbone of Botswana's economy contributing about 40% to the country's GDP when the country gained independence in 1966 (Mhozya, 1992). The livestock subsector especially cattle, contributed the most (80%) to agricultural GDP[1]. Livestock plays an important role to Botswana's economy as it exports beef, live animals and animal products to the European Union Market. Livestock is the backbone of the rural poor as they mainly dependent on livestock for their livelihoods through employment creation, serving as a source of income, investment, draught power for ploughing fields, provision of organic fertilizer and used for bride price payments (cattle) and (Nkondze, Manyatsi, & Masuku, 2013).

However agricultural performance has been declining over the years and currently stands at 2.0% contribution to GDP and has generated more than 15 percent employment mostly in the rural areas (BOB, 2016). According to Malema (2011) this massive decline in the performance of the agriculture sector has been attributed to unfavourable climatic conditions and failure to improve the traditional way of farming into commercial farming. The (IPCC, 2007) predicts that even with a smaller temperature rise of 1–2.5 degrees Celsius, the consequences could still be severe, exerting extensive impacts on the livelihoods of many people. Over the years increases in temperatures, floods, and erratic rainfall patterns, have contributed to increased intensity and

[1] https://www.export.gov/article?id=Botswana-Agricultural-Sectors

occurrence of droughts which negatively impact on livestock. Droughts in Botswana are recurrent with a trend of one in four years being a drought year.

Botswana agriculture sector consists of the commercial and traditional systems and in this study we look at livestock production in the commercial system. Over the years there have been increasing efforts from government of Botswana to commercialise the agriculture sector for this reason this study will be focused on the commercial system.

It is expected that as the country develops, there is a natural decline in agriculture's GDP, but of concern is the reduction in the overall production of output in agriculture affecting food security (Dube, 2012). Despite these facts about the performance of agriculture, agriculture still contributes to the livelihoods of the poor as it is labour intensive and produces renewable resources. Hence the need to carry out this study to identify ways in which we can mitigate the effects of climate as the poor are the ones who are mostly affected by climate change.

The bulk of agriculture studies in Botswana (Chipanshi, 2003, Masale, 2006, and Dube, 2012) have focused on the effect of climate change on crop output. Little has been done on livestock despite the fact that livestock production makes a contribution of about 80% to agriculture's GDP (AgGDP) in Botswana (Kahaka, 2016; Seo & Mendelsohn, 2007). A recent study on 'Climate change perceptions and adaptation for livestock farmers in Botswana' (Kahaka, 2016) was carried out to assess how livestock farmers in Botswana perceive climate change and the different adaptation measures used by farmers to address climate change concerns in livestock. The study also shed some light on the barriers of adopting those adaptation strategies by farmers the four main ones were selling livestock, water harvesting, help from veterinary officers and livestock diversification. Livestock development interventions did not address climate change concerns in livestock.

In Africa, a new model called structural Ricardian was used to study the impacts of climate change on animal husbandry (Seo & Mendelsohn, 2007). The study used the Structural Ricardian method to estimate which species are selected for production given the net revenues from each selected animal. The Ricardian results were used to show how farmers change their behaviour in terms of livestock choice selection as a response to climate change.

In this study, we only focus on beef cattle. As climate warms, net incomes across all animals will decrease especially across beef cattle. This is because beef cattle are sensitive to warmer temperatures. Botswana as a beef exporting country and having comparative advantage on beef cattle in the agriculture sector should invest more on research on climate change and acquire increased knowledge on how climate change impacts on beef production. Local farmers should use adaptation and mitigation interventions that address climate change.

Therefore this study is a scholarly effort to expand on existing climate change knowledge by using the Ricardian method of econometric analysis to quantify the effect of climate change on net revenue from beef production in Botswana, and also measure the marginal impact of climate change on beef production which has not been done in the country. This will aid policymakers to recommend development interventions that appropriately address climate change on cattle. This will also inform natural disaster management strategies, legislative reforms to improve agriculture performance and improve food security in the country.

1.2 Problem Statement

Climate and weather greatly influence life on earth. They form part of the daily experience for human beings and are essential for food production, security and health. The African continent is very susceptible to impacts of climate change due to its low adaptive capacity (IPCC, 2007). Agriculture still remains the backbone of most African economies, and supplies up to 50% of household food necessities and up to 50% of household earnings (Rust & Rust, 2013). Most of the income is generated by beef cattle, dairy cattle, goats, sheep and chickens. Majority of the livestock has no protective structures and they graze off the land, thus there are reasons to expect that African livestock will be sensitive to climate change (Seo & Mendelsohn, 2007).

Beef cattle in most literature have been found to be highly sensitive to warm temperatures affecting their productivity. Botswana is a country that exports beef and has a large cattle population especially amongst the communal farmers. According to the various annual reports compiled by the Ministry of Agriculture, cattle population has been fluctuating over the years especially in the recorded drought years, affecting the beef exports.

In the 2015 report, cattle population and inventory census between 2004 and 2015 proved a decline in cattle numbers by 3.81 percent from 2,154,820 in 2004 to 2,072,683 in 2015. 2015 was reported a drought year[2]. Exports of beef (as a percentage of production) in 1980 were at 84.07 percent, in 1990 were 47.85 percent, 2000 were 70.25 and in 2002 at 42.57 percent (FAO, 2005). This confirms fluctuations in beef production and export levels. Drought in the country was reported for the years 1981-1987, 1991-1999, 2001-2005, 2007-2008, 2012 and 2015. Therefore with the above situation at hand there is a need to investigate the relationship between climate factors and beef production.

There have been increasing government efforts over the years to improve the agriculture sector especially in the livestock sector, but despite that the agriculture GDP contribution continues to be low currently at 2.0 percent. Botswana's beef industry is still challenged with satisfying high quality beef standards of the European Union (EU) market. The EU quota 18,916 tons (Stevens, Kennan, & Meyn, 2007) has not been filled over the last decades, despite the fact that the country still has preferential access for its beef exports (Seleka, 2017) which is a lost opportunity for Batswana. This encourages Botswana government to increase efforts to stimulate meat production.

Climate change is guaranteed to cause a further decline in the quality and quantity of cattle produced in the country especially for the communal farmers where large numbers of cattle are. This leads to increase in the numbers of cattle taken to the feedlots by farmers to be fattened in order to meet the criteria of the EU market before being sold to abattoirs and other countries. This process is quite costly to farmers and as such they tend to sell their cattle directly to local abattoirs and other local outlets instead of selling to the Botswana Meat Commission (BMC) hence a low supply of cattle to the BMC and ultimately low exports of beef.

Therefore it is important to understand the expected nonlinear relationship between climate change and beef production in order to find and use adaptation and mitigation measures that will address climate concerns in beef production and help improve on the outcome in the beef sector.

[2] http://www.statsbots.org.bw/sites/default/files/publications/Agric%20Stats%20Brief%202015.pdf

1.3 Objectives

The overall objective is to determine the impact of climate change on beef output (measured in metric tonnes) in Botswana over the 1980-2016 period. The specific objectives are:

a) To determine how climate change variables (rainfall, temperature and drought) affect beef production
b) To determine the effects of non-climate variables such as beef prices and outbreak of diseases that may have an influence on beef production
c) To recommend strategies for mitigating and adapting livestock production particularly cattle to climate change on the basis of empirical findings

1.4 Hypothesis

H_0 : Climate variables (rainfall, temperature and drought) have a significant impact on beef production.

H_1 : Non climate variables such as beef prices and outbreak of diseases have a significant impact on beef production.

1.5 Significance of study

This study looks at the challenges that Botswana is facing in the process of increasing local food production in order to be self-sufficient and reduce dependence on food imports. This study seeks to understand by quantifying the extent to which climatic factors impact on beef production in Botswana. Globally there is an increased demand for beef and beef products, and so producers are further encouraged to increase the cattle numbers and improve production to meet the demand in the beef market. Beef cattle is one of the most emission-intensive sectors (Saghaian, 2018), and cattle are very sensitive to warm temperatures. The study is expected to add to existing volume of literature on the subject matter and increase an understanding of factors that influence beef output. Such an understanding is likely to assist agricultural planners and policy makers to formulate development policies that are specific and appropriate in increasing food production based on the mitigation and adaptation strategies and cost of climate change in the economy.

1.6 Organization of the study

The remainder of this dissertation is organised as follows; chapter two provides the background of the agriculture sector in Botswana, while chapter three provides theoretical and empirical literature that relate to the study. Chapter four provides the conceptual framework and specifies an empirical model to be estimated as well as the estimation techniques. The data and scope of the study are discussed in this chapter. Chapter five presents a discussion of empirical results while chapter six presents conclusions, policy recommendations and possible areas for further research.

CHAPTER 2: CLIMATE AND AGRICULTURE IN BOTSWANA

2.1 Introduction

This section captures the climate conditions of the country, followed by the economic history of the agriculture sector in terms of its contribution to the gross domestic product (GDP). It also looks into the programs that the government has put in place to encourage and promote beef production in Botswana.

2.2. Economic structure and growth

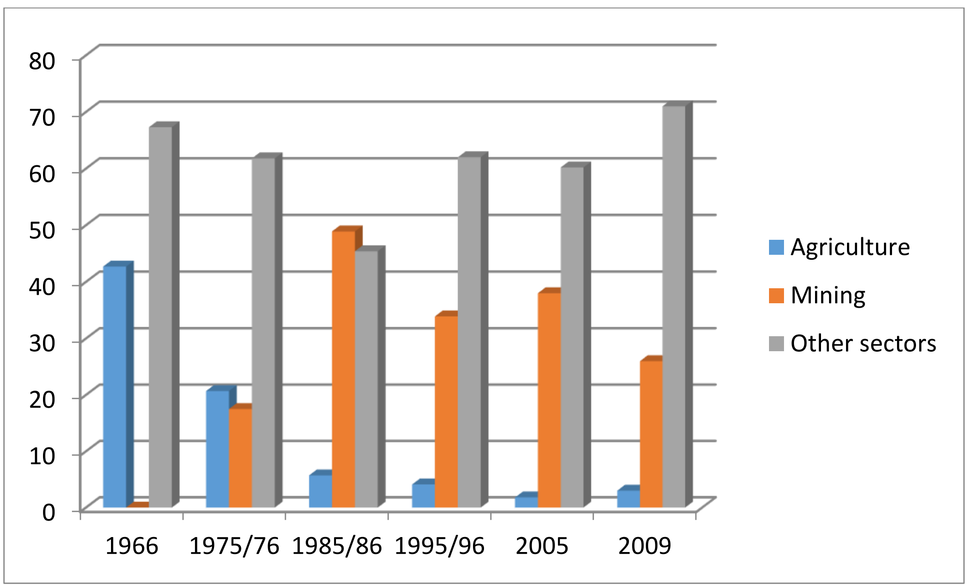
The Agriculture sector contributed the most to Botswana GDP at independence. Since the discovery of diamonds in the 70’s, the agriculture sector’s contribution has been declining (GOB, 2010). Agriculture plays a significant role of providing food, employment, income, and investment opportunities for the majority of the rural population (Tomicha, 2018).

The trends in the contribution of agriculture sector to GDP over the years have been quite small compared to other sectors like mining, manufacturing, trade and tourism. This has been largely attributed to low, unreliable and unevenly distributed rainfall, the occurrence of successive droughts, poor soil fertility, poor farm management, insufficient knowledge and training of extension agents and farmers in the country (Seleka, 1999). The increased contribution of other sectors to GDP relative to agriculture emphasizes government's efforts to diversify the economy away from traditional exports.

Currently agriculture contributes about 2.0 percent while the mining sector is the largest contributor to GDP at 19.9 percent (BOB, 2016). The diamond mining sector is the key source of government revenue, foreign exchange earnings and foreign direct investments. It uses a non-renewable resource which is capital intensive limiting opportunities for labour employment hence the great need for economic diversification to other non-mining sectors.

Below is a chart showing the various sectoral contributions to GDP in Botswana from 1966-2009;-

Figure 2.1: Sectoral contributions to GDP in Botswana from 1966-2009



(Siphambe H. N., 2005), (Botswana, 2010).

Agriculture at independence contributed 42.7 percent to GDP. The discovery of mining in the 1970s and persistent droughts in the 1980s led to agriculture's contribution to GDP reducing to

5.7 percent. The mining sector has since been the dominant sector in the economy and the agriculture sector has continuously showed a declining trend at around 2 percent in 2016 (BOB, 2016), while also showing a rapid growth of other economic activities. Our non-renewable based diamond mining sector experienced declining growth rates for the years 2007 to 2009, the periods that concurred with the global financial crisis in the year 2008/9. The decline in commodity prices of diamonds in the global market reduced demand for them, which led to less production of diamonds for exports and led to more output from the non-mining sectors such as agriculture, transport and communication and the hotels and restaurants which are showing a growth in spite of the recession (Malema, 2012).

Despite the agricultural sector presently contributing very little to overall GDP, the efforts to promote its growth are vital as the majority of rural households still depend on agriculture for employment, food and income. Agriculture is linked with other sectors through provisions of renewable primary inputs for production processes hence it will also important to develop the sector in order to help expand on others sectors. According to Statistics Botswana (2014), the agriculture sector is a labour intensive sector and almost 90 percent of whole rural labour force is engaged in agriculture directly or indirectly. The livestock subsector system is dominated by beef cattle production, and for the period of 1994 to 2013 it accounted for 46% to 65% of agricultural value added and has remained the leading agricultural activity (TRANSTEC and BIDPA 2010) as cited in (Seleka, 2017).

2.3. Livestock production and climate change

Climate change affects livestock production through animal health, nutrition and access to water. High and low temperatures lead to the emergence and re-emergence of infectious diseases that affect animal health. In Botswana one of the greatest challenges faced by the livestock agricultural sub sector is that of outbreaks of diseases. Livestock disease outbreaks result in widespread consumer alarm, cause isolation from productive markets affecting trade and resulting in severe effects on incomes, increased livestock deaths and some livestock diseases also affecting human health. The success of the livestock industry depends on livestock health (Chaudhary, 2013).

Some of the cattle diseases found in Botswana are anthrax, Contagious Bovine Pleuropneumonia (CBPP), measles and foot and mouth disease. Their spread and intensity in cattle are aggravated by changing climate conditions creating favourable environments for the growth of bacteria and spread of viruses. These affect the health of cattle by lowering the quality and quantity of meat produced thus failure to meet the EU meat standards, and also affects the health of the local population.

Climate change causes declining rainfall patterns, increasing temperatures and recurrent drought which affects cattle production through feed losses and increased demand for the country's limited water resources. During drought there is an increase in the depletion of underground water sources due to increased demand for them and dam inflows are less due to little or no rain. According to a local survey in 2014, there were recorded cattle deaths rates of about 12.8 percent and reduced birth rates of 48.8 percent in 2014 from 52.1 percent in 2013[3]. The year 2013/14 was declared a drought year by the government of Botswana.

Increase in temperatures increase the occurrence of heat stress in animals affecting their reproduction and their growth and in extreme cases may lead to their death. High temperatures also reduce the availability of livestock feed affecting their growth and productivity (Kebede, 2016).

Human health is affected through an increase in the occurrence and intensity of heat waves, increase in the spread of diseases and creation of new ones, which will affect their labour productivity and result in low production of food thus worsening food insecurity in low income countries. This may also increase the levels of malnutrition amongst the population in low-income countries as they are likely to be vulnerable to the adverse effects of climate change.

Adaptation strategies used by farmers in response to climate change are switching species for example, from dairy cattle to beef cattle or from cattle to small ruminants in the short run, reducing livestock numbers by selling them to cut on possible losses as a result of climate change. Diversification of breeds and animals to those that can easily adapt to changing climate conditions for example species mix to more drought resistance breeds (Kabubo-Mariara, 2008), using improved feeding practices to improve the animal diet which can promote an increased

[3] http://www.statsbots.org.bw/sites/default/files/publications/Annual%20Agriculture%20Survey%20%202014.pdf

intake of feed by the animal especially during dry seasons, therefore reducing animal malnutrition and death. Farmers also demand for livestock insurance schemes and use better water management methods to improve livestock production.

2.4. Government policies in the livestock sub-sector

In 1991, the government of Botswana changed its agricultural policy from food self-sufficiency to food security (Seleka, 1999). The main objective was to diversify the agriculture sector production base for more incomes, providing increased access to food at household level (Seleka, 1991) and national level, increase agriculture output and increase employment opportunities in the sector. The National Policy on Agricultural Development (NPAD) in 1991 also encouraged commercialization of cattle by the privatization of ranches. There was unregulated use of underground water reserves and overgrazing of pastures which ultimately led to its failure as problems were not addressed.

In 1975, the Tribal Grazing Lands Policy (TGLP) was implemented and it provided fencing and creation of commercial ranches. It provided grazing control, better range management and increased commercial productivity and activity (Petitt, 2016). As a result, there was an increase in the numbers of quality cattle sold to the BMC which ultimately led to a strong growth in beef exports. However the TGLP policy programme success was short lived as Odell (1980) noted that the process of implementation reduced the effectiveness of the TGLP in mitigating overgrazing in ranches.

Government provided financial assistance through the 1982 the Financial Assistance Policy (FAP) in attempts to diversify the economy and increase production. Molokomme (1992) stated that FAP offered training to citizens to upgrade their production skills, created sustained and varied employment for the unskilled workers, promoted citizen owned projects and produced goods for the export market and for import substitution (Seleka, 1999). There was however an abuse of funds in that animals were used to channel money from government to farmers rather than promoting productivity and as such not much diversification occurred in the livestock sector. The policy ended in 2001 when Citizenship Entrepreneurial Development Agency

(CEDA) took over to be the main source of funds offering subsidized loans to farmers especially youth and women who wanted to start productive enterprises intensifying the commercialization of the livestock sector (Petitt, 2016).

The fencing policy of 2001 helped farmers manage their livestock number well and production. The disadvantage of this policy is that there is expansion of livestock production into wildlife areas and the survival of wildlife is threatened in Botswana (Mbaiwa, 2006).

In 2006 Livestock Management and Infrastructure Development (LIMID) was developed by government (J. Moreki, 2010). Its objectives are to promote improved productivity of cattle and small stock, to improve livestock management and range resource management, to aid water development, to reduce poverty by providing resources to the poor and to provide infrastructure for safe and hygienic processing of poultry products. LIMID offers support schemes to citizens only. The programme is a success in most districts and most farmers still continue to benefit from the programme. Special Economic Zones (SEZ) law adopted in 2015 as a way to increase output in the agriculture sector but despite all these interventions the food security situation in the country and economic diversification process has not improved extensively.

3.0 CHAPTER 3: LITERATURE REVIEW

3.1 Introduction

The aim of this chapter is to review both the theoretical and empirical literature that other researchers have established with regard to the impact of climate change on agriculture. The empirical results vary from one study to another and in other cases general conclusions are drawn.

3.2 Theoretical literature review

In literature there are two types of economic assessment models, the general equilibrium models and the partial equilibrium models, that help us to understand the effects of climate on agriculture. General equilibrium models look at the economy as a complete system of interdependent sectors (industries, factors of production, institutions and the rest of the world for example Computable general equilibrium model (CGE) models. Climate change directly or indirectly affects different sectors of the economy and models that integrate the complex interactions among different sectors are needed.

According to Deressa et al (2009) there are some limitations of the CGE models and they include difficulties in model selection, parameter specification and functional forms, calibration problems, high skills needed to develop and use them, absence of statistical tests for the model specification and their complexity. According to a paper by (Gebreegziabher, 2011) CGE models are used to analyse the economy wide and distributional welfare effects of climate changes on Ethiopia’s agriculture.

Partial equilibrium models which are used in most literature are the production function and the Ricardian approach (Nhemachena, 2009). The production function is a model for which each crop links its yield to the physical, biophysical and biological environment (Ouedraogo, 2006). Production function method relies on experimental production functions to predict environmental change but does not take into account farmer’s adaptations as a response to social, economic and environmental changes.

To overcome the main weakness of this approach most studies have used a method that corrects for the bias in the production function called the Ricardian approach. The ricardian is a model that uses a cross-sectional approach to study agricultural production and was developed by Mendelsohn et al. (1994) to estimate the impact of climate change on agriculture. It was originally formulated to address the limitations of the production function approach when measuring effects of climate change on agriculture (Mendelsohn, Nordhaus, & Shaw, 1994). The ricardian method estimates the impact of climatic, socio economic and geographical variables on farm revenues and land value with regards to livestock and crop production as climate changes (Mariara & Fredrick, 2006).

Mendelsohn et al., (1994) based their model on the assumption that there was perfect competition in the market for inputs and outputs, and that in all plots interest rates, capital per acre and rate of capital gains are the same. Deressa and Hassan (2009) mentioned that the ricardian model accounts for the indirect substitution of different inputs and the introduction of different activities/livestock species. The approach has been criticized for overestimating the damage from climate change as the analysis makes forecasts based on current farming practices and does not capture future changes affecting agriculture such as technical change. According to McKinsey and Evenson, (1998) technology has increased farm performance over the years and therefore it is important to include technical change in forecasts. On the other hand, to date technological change has not affected climate sensitivity. Furthermore, technological development has not specifically been designed to enhance heat tolerance, and that the historic interaction between technology and climate appears to be insignificant (McKinsey, 1998).

The Ricardian method does not measure transition costs of when a farmer changes from one livestock species to another suddenly. It assumes prices are constant (Cline, 1996) and does not include carbon fertilization effect, which leads to a bias of overestimating benefits and underestimating damages. Also it has been criticized for reflecting current agricultural policies and not being based on controlled experiments across farms.

Despite these criticisms, increased evidence has shown that the bias introduced by the Ricardian assumptions is likely to be small ((Mendelsohn & Nordhaus, 1996), (Kurukulasuriya & Mendelsohn, 2008). In the Ricardian method it is assumed that the farmer maximizes net income by choosing which livestock to purchase and which inputs to apply. We follow Seo and Mendelsohn (2006a) as cited in (Kabubo-Mariara, 2008):

$$Max\, \pi = P_{qj}\, Q_j\, (L_G, F, L, K, C, W, S) - P_F F - P_L L - P_K K \dots \dots \dots \dots (1)$$

Where:

π is net income

P_{qj} is the market price of animal j

Q_j is the production function for animal j

L_G is grazing land, F is feed

L is a vector of labor inputs

K is a vector of capital inputs

C is a vector of climate variables

W is available water

S is a vector of soil characteristics

P_F is a vector of prices of each type of feeds

P_L is a vector of prices for each type of labour

P_K is the rental price of capital

The farmer chooses the species j and the number of animals that maximizes profit. The resulting net income can be defined as:

$\pi^* = f(P_q$, C, W, S,$P_{F,}P_L, P_K)$...................... (2)

The Ricardian function is derived from the profit maximizing level of equation (2) and explains how profits change across all the exogenous variables facing a farmer. The change in welfare (ΔU) resulting from climate change fromC_0 to C_1 can be measured using the Ricardian function as follows;

$\Delta U = \pi^* (C_1) - \pi^*(C_0)$ .... (3)

The Ricardian model treats a farmer as though he/ she is an income generating unit. This assumption fits large farms, and it can be also applied to small farms by evaluating household labour and own consumption (Seo & Mendelsohn, 2006a).

Kabubo-Mariara (2008) estimated two models, one for net value of livestock (stocks) and the other for net revenue of livestock (flows). It gave the final model as:

$\pi = \alpha_0 + \alpha_1 T + \alpha_2 T^2 + \alpha_3 R + \alpha_4 R^2 + \alpha_5 Z + \varepsilon$ …………… (4)

Where: T and T^2 capture levels and quadratic terms for temperature, R and R^2 capture levels and quadratic terms for precipitation. Z is a vector of socio-economic variables and ε is a random disturbance term. The quadratic terms for temperature and precipitation are expected to capture the nonlinear shape of the climate response function. When the quadratic term is positive, the net revenue function is U-shaped, but when the quadratic term is negative, the function is hill shaped.

We can then derive the expected marginal impact of temperature and rainfall changes on livestock production from equation (4). It gives us:

$$E\left[\frac{\partial \pi}{\partial T}\right] = \alpha_1 + 2\alpha_2 E[T] \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$E\left[\frac{\partial \pi}{\partial R}\right] = \alpha_3 + 2\alpha_4 E[R] \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

3.3 Empirical literature review

A study by Mendelsohn et al. (1996) as cited in Maganga and Malakini, (2015) measured the economic impact of climate change on land prices using the Ricardian method approach. The study was based on cross sectional data, for almost 3000 countries in the United States. Results showed that all seasonal temperatures in all seasons except for autumn increased farm values. Estimated impacts of global warming on US agriculture using the Ricardian method were significantly lower than estimates from the traditional production function approach.

The Ricardian method used in Italy (Bozzola, 2017) found that most of the seasonal climate coefficients are highly significant. The climate coefficients of the squared terms were significant implying that the climate effects tend to be nonlinear. A 1 °C increase in summer temperature reduced land values by 62% for Italy as a whole. An increase of 1 °C in spring increased land values by 37%. The effect of a marginal change in winter and autumn temperature was insignificant. The consequence of a uniform increase of 1 °C across all four seasons is the sum of the seasonal effects. Seasonal effects are working against each other and will have no significant effect on Italian farm values. Increases in just summer temperatures, are however instantly harmful and having too much precipitation is harmful too. Effects of precipitation differ across regions in Italy and annual effect of more precipitation is harmful in some regions and beneficial in other regions. Having too much of it is however harmful.

According to (Khaqan, 2016) the Ricardian method examined the impact of climate change on livestock husbandry (milking large ruminants) in Pakistan. They incorporated the months for climatic variables (temperature and precipitation) which are Rabi (January to April) and Kharif

(July to September) season, in which green fodder is harvested for dairy animals. Results showed that livestock production in Tehsil Faisalabad is highly sensitive to climate change and they have a non-linear relationship. Kharif precipitation and temperature have more adverse effects because temperature and precipitation are high. Household size and value of milking animal variables both had a positive significant relationship with net revenue from milk production. The age of the head of the household variable negatively insignificantly impacts on the revenue from milk production. It was recommended that adaptation methods of cross breeding animals should be used in order to help them resist heat and improve their milk production, and also during hot seasons give daily baths to animals to help their body temperature remain stable (Khaqan, 2016).

In Kenya, the Ricardian method was used to study the impacts of climate change on livestock (Kabubo-Mariara, 2008). Livestock is highly sensitive to climate change and there is a nonlinear relationship between the climate change and livestock productivity. The estimated marginal impacts of climate change on livestock production were assessed by calculating the change in mean net value of livestock and mean net revenue resulting from a unit change in temperature and precipitation. The results proposed that summer temperatures have negative significant impacts on net value of livestock, but winter temperatures are positive and significant. The overall impact of rising temperatures is an increase in livestock productivity.

The marginal impacts of precipitation are more modest than for temperatures, but the elasticities are much higher. High winter precipitation is advantageous for livestock production but high spring precipitation is harmful. Increased precipitation will lead to a fall in net value of livestock. A 1% increase in mean precipitation reduces net revenue by 6%. Farmers are likely to adapt to climate change by changing from livestock to crop production or by species mix. In the long run livestock farmers are likely to incur huge livestock losses as a result of global warming.

A study of the econometric analysis of the impacts of climate change on livestock production was done at watershed level and county level in Qinghai Province, China. The results indicated that higher temperatures coupled with increase in precipitation, humidity at small watershed level and county level, and sunshine duration were all beneficial to livestock production, except in areas where increases in temperature reduced livestock output (Yanfei Li, 2013).

A study in Swaziland (Nkondze, Manyatsi, & Masuku, 2013) used the Ricardian method to investigate the impact of climate change on livestock in the Mpolonjeni Area Development Programme. The study was both qualitative and quantitative in that it used primary data from households (through interviews) on their perceptions of climate change in their area to establish impacts of climate change. These were in terms of changes in temperature, changes in rainfall patterns and drought, also through the observed livestock data on cattle and goats populations from the Ministry of Agriculture. Livestock data was from the years 1983 to 2011 to establish the impact of climate change on livestock production in the Mpolonjeni Area Development Programme. 99.4% of the respondents suggested that temperatures were increasing, 98% revealed that rainfall patterns were erratic and 95% revealed that they experienced drought at one point.

The Ricardian model and descriptive statistics were used to establish the impact of climate change on goats and cattle populations. The dependent variable was net revenue from goats or cattle and the independent variables that explain climate changes were temperature and rainfall. Temperature and rainfall data were acquired from Swaziland Meteorology Department to establish their trends in the Mpolonjeni Area Development Programme. The results indicated that net revenue from goats was sensitive to winter temperatures, winter temperatures squared, and winter rainfall squared. The study concluded that climate change impacts negatively on livestock production which is consistent with the expected results for this study.

In Botswana, the Ricardian method was used to measure the impacts of climate change on arable crop production from 1980-2008. The analysis indicated that increasing temperatures and decreasing rainfall were both damaging to Botswana arable agriculture and that climate change is likely to impose significant costs on the economy (Dube, 2012).

Most literature regarding climate change and agriculture have proven consistently that increasing climate variables have significant and negative effects on agriculture. This study is expected to shed light on the impacts of climate change on agriculture in Botswana with special reference to commercial beef cattle farmers.

3.4 Conclusion

The empirical studies have shown that different techniques on analyses have been used by different authors to examine the impacts of climate change on agricultural production over a period of time. The studies reviewed include the ones that employed the use of Computable General Equilibrium (CGE) model and the Ricardian model. Most studies that used net revenue and land value as dependent variables, climate variables such as rainfall, temperature and drought were significant in affecting the dependent variable. Therefore, literature regarding climate change and agriculture has proven consistently that climate variables have significant and negative effects on agriculture. This study is expected to shed light on the impacts of climate change on agriculture in Botswana with special reference to commercial beef cattle farmers. This study identified gaps to be filled and these gaps are the use the Ricardian method in beef production.

CHAPTER 4: METHODOLOGY

This chapter specifies the conceptual framework, the model to be estimated, discussion measurement of the variables to be included in the model and also their expected signs. The chapter further discusses the data analysis methods employed and provides the data sources and data collection methods.

4.1. Conceptual framework

Different models have been developed and formed the basis for most of the empirical studies on climate change and agriculture production. In this study, the impacts of climate change on beef production is examined using time series data from 1980- 2016 by adopting the Ricardian method, following the conceptual framework used by (Dube, 2012) and extended using adapted ideas from the model used in Kenya (Kabubo-Mariara, 2008, Nyangena, 2016), to measure the impacts of climate change on beef production. The Ricardian method has been widely used to measure impacts on agriculture for example in crops (Kurukulasuriya & Mendelsohn, 2008; Charles Nhemachena, 2010; Seo & Mendelsohn, 2008a) and livestock (Nkondze, Manyatsi, & Masuku, 2013; Seo & Mendelsohn, 2007; Seo & Mendelsohn, 2008b). The distinguishing factor is that (Dube, 2012) was focused on crops (sorghum and maize) and used panel data, while in this study the focus is on quantifying the impact of climate change on beef production and uses time series data.

4.2. Econometric specification of the model

Econometric time series data on beef production require an appropriate choice of regression specifications and estimation methods. The model is;

$$Q_i = \beta_0 + \beta_1 P_{t-1} + \beta_2 R_t + \beta_3 T_t + \beta_4 D_t + \beta_5 OD_t + \varepsilon_t$$

Where: Q_i = Beef production, P_{t-1} = Beef producer price variable, R_t = average annual rainfall, T_t = average annual temperatures, D_t = Drought period from 1980-2015 (captured as a dummy variable), OD_t = Outbreaks of Diseases (Captured as a dummy variable) and ε_t= error term.

4.2 Variable definition, measurement and expected relationship

The choice of the dependent variable depends largely on data availability.

Q_i = Beef Production

This refers to the amount of beef production measured in kilograms (kg) for all the years from 1980 to 2016.To get beef production we multiplied the Carcass Dressing Mass (CDM) by the number of cattle.

P_{t-1} = Beef producer price variable

It is assumed that production decisions this year are based on previous year's prices. This basically refers to the price at which commercial farmers sell their beef cattle to the Botswana Meat Commission (BMC).We use the weighted averages of beef cattle per grade in every year to find a single price of beef per year. As per the data provided by BMC, the prices were calculated by dividing the total amount spent on commercial farmers for each year by the beef production formula, that is, (total amount spent on commercial farmes/ CDM*number of cattle) to give us the price per kg of beef. Prices in the current year differ from the previous year's price. The prices to be used are in Pula per kg of beef. It is expected that a direct relationship exists between producer price and beef production. As prices increase, farmers are expected to be stirred to produce more yields, thus, average yield is expected to vary with price. According to Jefferies (2007), cattle producers in Botswana respond positively to cattle prices. The model adopts the previous year price variable because production decisions are based on previous year prices.

R_t= Average annual rainfall

The amount (in millimetres) and frequency of rainfall in the country influences the production of beef. The country has four seasons and among these seasons only one receives the highest rains which are needed in crop and animal production. The monthly rainfall measurements for a year are summed together and then divided by 12 months in order to capture the average rainfall per year. The averages are then fitted into the regression model. There is a direct relationship between rainfall and beef production is expected. In Botswana agricultural production is highly dependent on the amount of rainfall in a particular period. Therefore the higher the rainfall, the more the availability of feed for livestock and increased access to water resources hence improved animal health and performance and thus increased beef production. The opposite is true. In Togo, (Mikémina, 2013) net farm revenue is expected to increase with high precipitation during the rainy periods which are the main growing seasons of Togo.

T_t= Average annual temperatures

The average monthly temperature variations for a year are summed together and then divided by 12 months in order to capture the average annual temperature. The averages are then fitted into the regression model. A positive relationship between temperature and beef production is expected because beef cattle are high sensitive to warm temperatures. Annual average temperature increases would lead to an increase in net revenue from livestock that adapt well to high temperatures and a decline in net revenues from those that do not respond well to rising temperatures (Kabubo-Mariara, 2008). For beef cattle summer temperatures exhibit a U-shaped relationship with net revenue but to winter temperatures the relationship was hill shaped to net revenue. This shows that climate has a nonlinear relationship with net revenue of beef cattle.

D_t= Drought period from 1980-2016

Depending on the time of drought occurrence, intensity and duration, cattle beef production is affected. In this study drought is used as a dummy variable where D=1 are the years with drought and D=0 are the years without drought. The expected relationship between drought periods and beef production is expected to be negative.

OD_t= Outbreak of Diseases

This employs the use of a dummy where, D=0 for years without outbreaks of cattle diseases and D=1 for the years with outbreaks of cattle diseases. This study considers years of disease outbreaks to be the years in which the Ministry of Agriculture recorded an outbreak of Foot and Mouth (FMD) cattle disease in the country. An inverse relationship between years of disease outbreaks and beef production is expected because diseases are expected to have a major impact on the supply of beef as the occurrences are beyond the farmer's control.

4.3 Data and instruments of collection

The study relied on secondary data that were collected through documented literature. Annual report documents from the Ministry of Agriculture provided data on droughts, cattle disease outbreaks and the cattle population statistics, rainfall and temperature data were sourced from the Department of Meteorological Services and data on beef prices were sourced from the Botswana Meat Commission (BMC).

4.4 Procedures for estimations

a) Testing for stationarity

The first step is testing for stationarity using the Augmented Dickey Fuller and Phillips Perron tests because a multiple linear regression based on non-stationary data sets will yield spurious relationships amongst beef production and the independent variables, which reduce the validity of the statistical tests. The non-stationary time series can be made stationary by differencing it a number of times until it is stationary.

b) Co-integration tests

After doing stationarity tests, we proceed to test for the long run relationship between the variables. If there is no cointegration we estimate an Unrestricted Vector Auto Regression (VAR) to quantify the impact of climate change on commercial beef production in Botswana. If there is cointegration, the implication of this result is that we have to proceed and estimate a Vector Error Correction Model (VECM) to establish the nature of the long run relationship among the series.

c) Heteroscedasticity and serial correlation tests

Heteroscedasticity and serial correlation tests are then done to ensure that the model satisfies some assumption about the residual errors such as no heteroscedasticity, no serial correlation and no multicollinearity. The Autocorrelation LM test was used to diagnose any presence of serial correlation among the residual errors.

Table 4.5: Explanatory variables used in the Ricardian Model and their expected signs

Variables	Measurement	Expected sign	Data and data sources
Beef production (dependent)			Average Carcass Dressing Mass data and cattle numbers over the years, BMC annual reports and Ministry of Agriculture reports
Average Annual temperature	Degrees Celsius	(+/-)	Annual Rainfall statistics, Department of Meteorological Services
Average annual rainfall	Millimetres	(+/-)	Annual Rainfall statistics, Department of Meteorological

			Services
Outbreak of diseases	1=Yes: 0=No (Dummy variable)	(-)	Years of foot and mouth cattle disease outbreaks, Ministry of Agriculture Annual Reports in Botswana
Beef producer prices	Pula per kg of beef	(+)	Average weighted prices of beef and quantities sold by the Botswana Meat Commission (BMC), BMC.
Drought	1= Yes: 0=No (Dummy variable)	(-)	Recorded Drought years, Ministry of Agriculture Annual Reports in Botswana

CHAPTER 5: RESULTS ANALYSIS AND INTERPRETATION

5.0 Introduction

This chapter presents the empirical findings and analysis of the impact of climate change on commercial beef production in Botswana from 1980- 2016. The chapter is organized into four sections; Section 5.1 briefly describes the nature of the data and variables used in the model. Section 5.2 conducted the test for the presence of unit root in order to determine the stationarity and the order of integration of the variables included in the model. Section 5.3 presents and discusses the results of co integration of the variables. Section 5.4 are the diagnostic tests results, section 5.5 presents the estimation of the Vector Error Correction Model (VECM) and Section 5.6 presents the Variance decomposition of the average growth rate of beef production.. It is in this section that the econometric interpretations of the empirical results are presented. The econometrics package E-views 9 was used to analyze the data.

5.1 Nature and description of the data and variables

Descriptive Statistics

Descriptive statistics offer a simple summary about the basic structures of the sample. The measures of central tendency are used to provide numerical information about the typical observation in the data (Hollingsworth, 2016).It also determines if the data have a tendency to centre on some value. The results are shown in table 5.1 below:

Table 5.1: Descriptive Statistics

	BP	P	R	T
Mean	25771890	8.745223	32.76539	20.85200
Median	22982895	5.993547	29.86389	21.39209
Maximum	48651200	26.02282	58.74722	22.61863
Minimum	5864038.	1.178683	18.18333	15.41218
Std. Dev	10562816	7.583116	9.715647	1.753090
Skewness	0.582094	1.031810	0.734758	-1.642030
Kurtosis	2.712479	2.747179	2.893372	4.678331
Jarque-Bera	2.216921	6.663769	3.346720	20.96952
Probability	0.330067	0.035726	0.187616	0.000028
Sum	9.54E+08	323.5733	1212.319	771.5238
Sum Sq. Dev.	4.02E+15	2070.132	3398.177	110.6397
Observations	37	37	37	37

Source: Eviews results

Beef production (BP) over the period of 1980-2016 (37 observations) has an average of 25771890 kgs or 25771.89 metric tonnes and the standard deviation of 10562816 kgs or

10562.816 metric tonnes. The producer beef price variable has an average of P8.745 per kg and a standard deviation of P7.583 per kg. Rainfall has an average of 32.77 millimeters (mm) and standard deviation of 9.716 millimeters (mm). Temperature has an average of 20.852 degrees Celsius ($^{\circ}C$) and a standard deviation of $1.753^{\circ}C$.

Skewness is an indicator of used in distribution analysis as a sign of asymmetry and deviation from a normal distribution. Skewness greater than zero shows a right skewed distribution, most values are concentrated on the left of the mean, with extreme values to the right. Skewness less than zero shows a left skewed distribution, most values are concentrated on the right of the mean, with extreme values to the left while skewness equal to zero shows that the mean and median are equal, that is, the distribution is symmetrical around the mean.

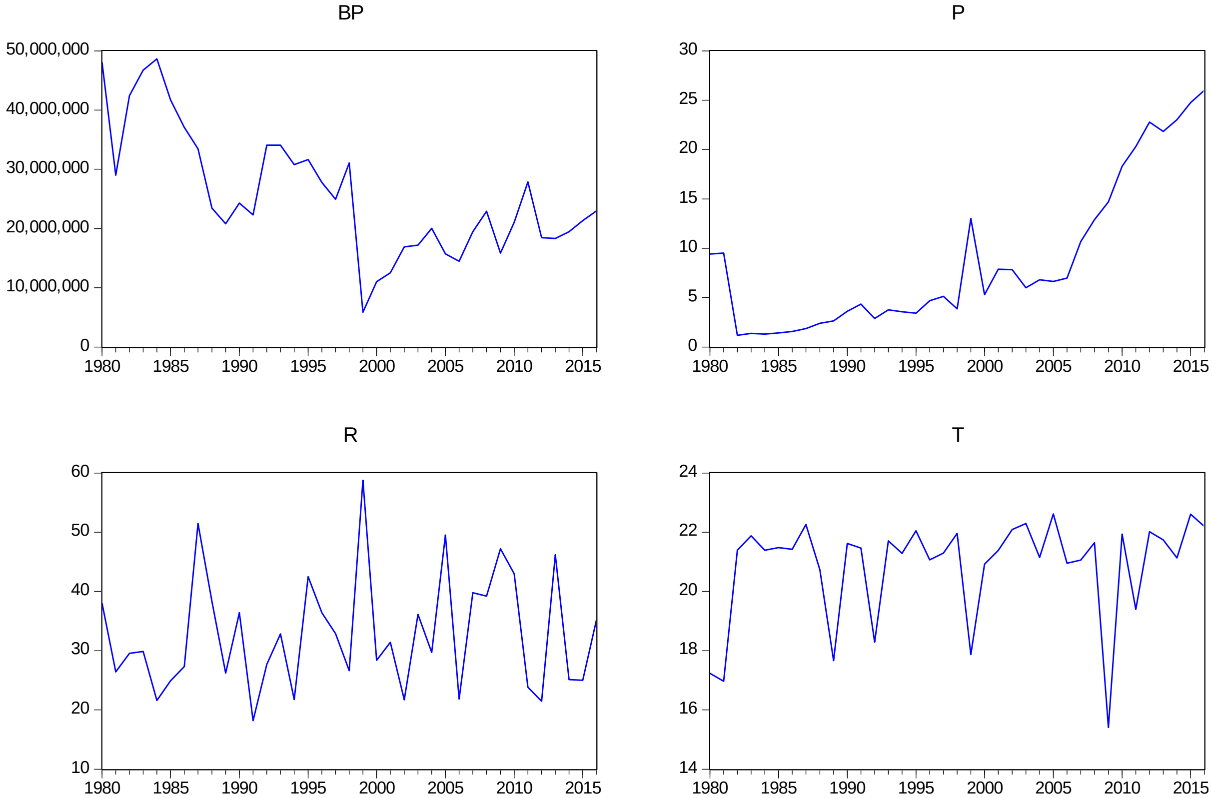
From the above, temperature (T) has a negative value for the skewness which means it is skewed to the left. Beef production, beef producer prices (P) and rainfall (R) have a positive value of skewness meaning that they are skewed to the right.

Kurtosis indicates whether the distribution is heavily tailed (a lot of data in the tails) or lightly tailed (few data in the tails) compared to a normal distribution. Kurtosis that is equal to 3 is called Mesokurtosis distribution and is a normal distribution. Kurtosis that is greater than 3 is called Leptokurtosis distribution, and has a sharper than normal distribution with values concentrated around the mean and has thicker tails. There is a high probability for extreme values. Kurtosis that is less than 3 is called the Platykurtosis and is flatter than a normal distribution and has a wider peak with values widely spread around the mean. The probability for extreme values is less than for a normal distribution. Temperature has a kurtosis value of more than 3 implying that the distribution is peaked relative to normal distribution. Beef production, beef producer prices and rainfall have kurtosis value near the expected value of 3 therefore they have a fairly standard normal distribution, that is, the data is fairly symmetric.

Graphical representation of the behavior of the variables:

Figure 5.1 below shows the graphical representation of the behaviour (trend) of the variables over the years.

Figure 5.1: Graphical representation



Source: Eviews results

5.2 Unit root test

A stochastic or random time series is said to be stationary if its mean and variance are constant over time. Stationarity or non-stationarity of a series can strongly influence its behavior and properties. Non stationary time series has a time varying mean and variance and creates a problem of spurious regressions with questionable or invalid results. Tests for stationarity used are the ADF test which accounts for autocorrelation and the PP test which is more superior to the ADF test. Below are the unit root test results:

Table 5.2: Unit root test of variables

VARIABLE	AUGMENTED DICKEY FULLER TEST (ADF)				PHILLIPS PERRON TEST (PP)			
	LEVELS		FIRST DIFFERENCE		LEVELS		FIRST DIFFERENCE	
	Stat	**Prob**	**Stat**	**Prob**	**Stat**	**Prob**	**Stat**	**Prob**
LBP	-3.012133	0.0432	-8.339266	0.0000	-2.934399	0.0513	-8.955258	0.0000
LP	0.635908	0.9882	-3.911277	0.0057	-1.128854	0.6937	-7.437213	0.0000
LR	-6.798907	0.0000	-3.838847	0.0072	-6.897155	0.0000	-41.13639	0.0001
LT	-6.067758	0.0000	-3.681003	0.0105	-6.119975	0.0000	-11.69461	0.0000

Source: Eviews results

H_0: Non stationary

H_1: Stationary

The above results are interpreted as follows:

- Average growth rate of beef production (LBP) is stationary at levels for both the Augmented Dickey Fuller (ADF) test and the Phillips Perron (PP) test. We reject the null hypothesis (H_0) for probability that is less than 5% and 10% level of significance. Therefore we conclude that BP is stationary (H_1) at levels.

- The log of the beef producer price (P) variable is showing that it is non stationary at levels for both the ADF and PP tests. The probabilities are greater than 10% therefore at levels we fail to reject the null hypothesis. Price is stationary at first difference.

- Log of rainfall (r) has a probability of less than 5% at levels for both the ADF and PP test results, therefore we reject the null hypothesis and say it is stationary (H_1).

- Log of temperature (t) has a probability of 0.0000 that is less than 5% at levels therefore it is stationary.

Given the unit root properties of each series, the next step is to establish if there is a long run cointegrating relationship among the variables using the Johansen cointegration test.

5.3 Johansen cointegration test

Cointegration refers to the existence of a long run relationship between variables. The results for the cointegration test are shown below:

H_0 : No cointegration

H_1: There is cointegration

Table 5.3: Cointegration trace test

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**

None *	0.614413	64.13751	54.07904	0.0049
At most 1	0.400954	30.78293	35.19275	0.1385
At most 2	0.263392	12.84834	20.26184	0.3761
At most 3	0.059550	2.148880	9.164546	0.7479

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.614413	33.35459	28.58808	0.0113
At most 1	0.400954	17.93458	22.29962	0.1824
At most 2	0.263392	10.69946	15.89210	0.2749
At most 3	0.059550	2.148880	9.164546	0.7479

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

Source: Eviews results

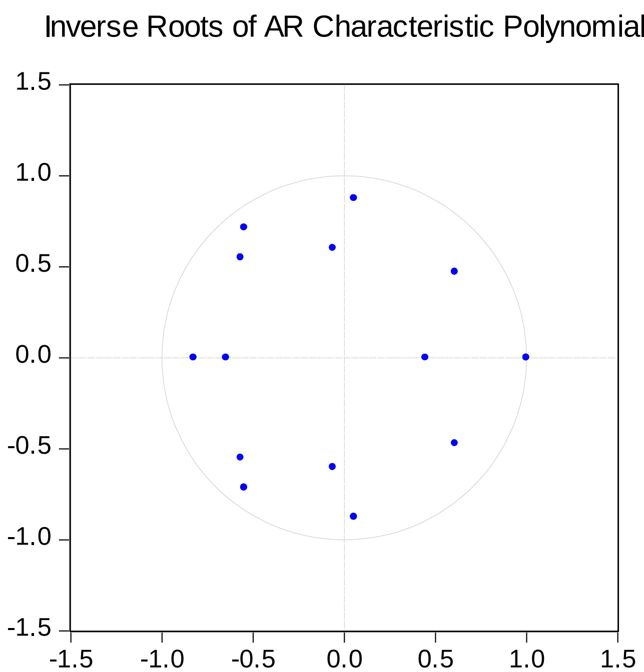
From the above Eviews results there is one cointegrating equation. We reject the null hypothesis of no co-integration when probability is less than 10 % and conclude that there is cointegration. The implication of this result is that we have to proceed and estimate a Vector Error Correction Model (VECM) to establish the nature of the long run relationship among the series.

5.4 Diagnostic tests

5.4.1 Stability test

The AR roots graph is used to check the stability of the model. Below are the AR Roots results:

Figure 5.2: AR Roots Graph



Source: Eviews results

All the AR roots lie within the unit circle except for only one root that lie on the circumference of the circle. This stability results show that the null hypothesis of stability is not rejected, thus the model is stable. Therefore, the model is appropriate for further analysis and will be good for policy recommendations.

5.4.2 Serial correlation and heteroscedasticity

It is common practice to treat the terms autocorrelation and serial correlation synonymously although some authors prefer to distinguish the two terms. In this study they are treated synonymously. Autocorrelation is defined as correlation between members of series of observations ordered in time series (time series data) or space (cross sectional data) (Gujarati & Porter, 2009). Classical linear regression models assume that there is no autocorrelation among the disturbances u_i. Autocorrelation of the disturbances usually happens when a series is non stationary. Autocorrelation may also arise when wrong functional forms are used in estimating the model. Testing for autocorrelation helps identify any relationship existing between residual values u_i and any lagged values. The LM test is used to test for autocorrelation under the null hypothesis of no serial correlation.

Heteroscedasticity occurs when the variance of the model's errors is not constant over a specific amount of time. Heteroscedasticity results in standard errors that are highly likely to be incorrect. The null hypothesis is that there is no heteroscedasticity in the model.

Table 5.4: Serial Correlation LM and Heteroscedasticity Tests

	Autocorrelation LM Tests	**White Heteroscedasticity Test**
	LM Statistic	**Chi-square**
Test statistic	11.95523	284.1491
Probability	0.7471	0.4197
Conclusion	Fail to reject the null hypothesis	Fail to reject the null the hypothesis

Source: Eviews results

H_0: There is no autocorrelation

H_1: There is autocorrelation

H_0: There is no heteroscedasticity

H_1: There is heteroscedasticity

As the p-value is greater than 10% at the lag of 3 (see appendices for lag length criterion results), therefore we fail to reject the null hypothesis and conclude that there is no serial correlation. The White Heteroscedasticity p-value results are greater than 10% at lag 3, which prove that we fail to reject the null hypothesis and therefore conclude that there is no problem of heteroscedasticity in the model. The results above indicate that the estimated parameters in the model are precise therefore can be used for economic analysis.

5.5: Vecm estimation

The VECM is used to estimate the impact of rainfall and temperature on average growth rate of beef production. The price variable is included in the model. The VECM allows for estimation of the short run dynamics within the model and captures the speed of adjustment to equilibrium from independent variable shocks.

Table 5.5 VECM LBP estimation Results

	Equation 1 LBP

ECT	-0.466856 [-4.21365]
D(LBP(-2))	-0.546754 [-2.25897]
D(LP(-1))	0.905302 [2.46069]
D(LR(-1))	1.154990 [3.46496]
D(LR(-2))	0.896478 [3.00321]
D(LR(-3))	0.724645 [3.50180]
D(LT(-1))	4.697037 [3.79288]
D(LT(-2))	3.436573 [3.11495]
D(LT(-3))	1.818442 [2.39118]
OD	0.046777

	[0.37515]
D01	0.297325 [2.52554]

Source: Eviews results

From the above results, R- squared (see appendices) which corresponds to the equation of interest is about 0.701343 indicating that about 70 percent of the variations in the dependent variable, that is, the average growth rate of beef production (LBP) is explained by the selected explanatory variables. This implies that the remaining 29.866 percent of changes in average growth rate of beef production are not explained by the variables employed in explaining the effects of climate change on beef production in Botswana from 1980 to 2016. It means that there are other variables not captured by the model whose absence is captured by the error term.

From the results in Table 5.5, the error correction term coefficient of the average growth rate of beef production (LBP) has a corrective negative sign and is significant. A significant error term implies a disequilibrium adjustment of each variable towards its long run equilibrium value. A significant error term provides validation of the existence of a long run relationship between the variables and speed of adjustment is 0.5 percent.

From the dynamics of the average growth rate of beef production (equation1), average growth rate of beef production is explained by its values, lagged values of average growth rate of beef production (LBP), a percentage change in beef producer prices (LP), the percentage change in average annual rainfall (LR), the percentage change in average annual temperature (LT), outbreaks of diseases (OD) and years of drought (D01). The lagged LBP carries a negative sign in lag 2 and is significant (see appendices), in lag 1 and 3 it is positive and insignificant.

The lag of beef producer prices is positive and significant in lag 1. This was expected because when price increases commercial beef producers will be motivated to increase their supply of beef cattle to the BMC to get more revenue from cattle sales. According to Jefferies (2007), cattle producers in Botswana respond positively to cattle prices.

The lag of average annual rainfall is positive and statistically significant in all the three lags. In Botswana agricultural production is highly dependent on the amount of rainfall in a particular period. Therefore the higher the rainfall, the more the availability of feed for livestock and increased access to water resources hence improved animal health and performance and thus increased beef production. In Botswana, the summer season begins in November and ends in March (BTO, 2013). Summer has high temperatures and has the highest rainfall especially in the months of January and February. The winter season is a dry season with no rainfall begins in May and ends in August. Most farmers in Botswana sell more cattle after the recovery season of summer usually in March, then after reaching their target income levels they relax and start supplying less cattle to BMC and opting to use other less strict selling outlets and as a result BMC exports sales suffer. Increase in precipitation results show that farmers are likely to switch from water sensitive species such as sheep to more water tolerant species such as beef and goats (Taruvinga, 2013).

Temperature coefficients in all the 3 lags are all positive and significant. This means that a one percent increase in temperature will result in an increase of about 4.7 percent, 3.4 percent and 1.8 percent on average growth rate in beef production in lag 1, lag 2 and lag 3 respectively. These results are consistent with the Ricardian model results in Kenya (Kabubo-Mariara, 2008), which concluded that the overall impact of rising temperatures was an increase in livestock productivity. Annual average temperature increases would lead to an increase in net revenue from livestock that adapt well to high temperatures and a decline in net revenues from those that do not respond well to rising temperatures.

These temperature results are expected because in Botswana the indigenous cattle breeds especially the Tswana breed which is mainly raised for meat production are well adapted to hot and dry environments thus have a high heat tolerance. There is continuous improvements in cattle breeds in Botswana as a result of a cross breeding exercise implemented on cattle to improve on their offspring genetic makeup of cattle so that the new breed will be able to further withstand very high temperatures and be able to reproduce and maintain good qualities for the EU market. Commercial farmers are also better equipped to adapt and mitigate their cattle to changing environments compared to most resource poor rural farmers across the country, with great emphasis on disease control and providing good quality feed to cattle especially during the drought years and using advanced technology during production. In the commercial farming sector there is controlled breeding, and cross breeding to improve on the genetic makeup of cattle so that they are able to further withstand very high temperatures and be able to reproduce and maintain a certain weight range and quality for the EU market. In Kenya, the Ricardian method was used to study the impacts of climate change on livestock (Kabubo-Mariara, 2008). The results revealed that the overall impact of rising temperatures was an increase in livestock productivity. Annual average temperature increases would lead to an increase in net revenue from livestock that adapt well to high temperatures and a decline in net revenues from those that do not respond well to rising temperatures.

The error correction term coefficient for the dummy variable outbreaks of diseases (OD) is positive and insignificant. This means that LBP does not adjust to correct departures from equilibrium in the short run. According to economic theory outbreaks of foot and mouth disease have a negative impact on the beef production because it would reduce the number of cattle supplied to BMC and as a result reduce beef exports to the EU market.

Drought involves a condition where there is a deficiency of rainfall over an extended period of time resulting in water shortage for some activity (Mutava, 2006) as cited in Dube (2012). Drought (dummy variable) coefficient is positive and significant. A one percent increase in drought will result in a 2.97 percent increase in average growth of beef production in Botswana. These results are unexpected in Botswana because there are persistent droughts in Botswana, one in four years being a drought year which will most likely affect the number of cattle supplied by farmers to the BMC. These results can be explained by cattle in Botswana being well adapted to the country's harsh semi-arid climate conditions with genetic improvements as a result of cross breeding and that is, they are tolerant to drought and heat. In cases where the farmer has both crops and cattle, during extensive drought seasons the farmer will more likely substitute crops for more cattle. According to Abate (2009), drought and decreasing rainfall led to poor regeneration of grass, heat stress in livestock and water shortages. This led to increased livestock mortality, vulnerability of diseases and physical deterioration due to long distance travel for water and pasture.

Based on the findings of the study, we conclude that the specific model does explain the impact of climate change variables on beef production in Botswana. This conclusion is based on the fact that the model is statistically significant as can be seen from the R^2 which is at about 70 percent. Most of the variables are positive and significant except outbreaks of diseases which is positive and insignificant.

The three climate variables in this study are rainfall, temperature and drought. In the case of rainfall and temperature, the lagged values are significant with an expected sign. Drought on the other hand has an unexpected positive sign and is significant. This demonstrates the complex nature of the interaction between climatic variables and beef production.

5.6 Variance decomposition

This section presents the variance decomposition analysis to determine the contribution of each shock to the variance of each endogenous variable. Indication on the contribution of shocks is essential for the reason that even if the impact on variables is estimated to be statistically significant, they may not be economically big. Table 5.6 shows variance decomposition of LBP.

Table 5.6: Variance Decomposition of LBP

Variance Decomposition of LBP: Period	S.E.	LBP	LP	LR	LT
1	0.342391	100.0000	0.000000	0.000000	0.000000

2	0.384636	95.03382	0.086842	2.049315	2.830019
3	0.416420	89.43314	0.215915	2.794607	7.556342
4	0.426349	88.09106	0.314845	2.879532	8.714562
5	0.435283	86.12729	0.850321	3.002238	10.02015
6	0.440295	85.47315	1.348024	2.938486	10.24034
7	0.445042	84.81463	1.768658	2.891526	10.52519
8	0.449303	84.20314	2.183609	2.837826	10.77542
9	0.452793	83.70598	2.528310	2.794506	10.97121
10	0.455996	83.20772	2.860406	2.756458	11.17542

Source:EviewsResults

The forecast error variance decomposition results in table 5.6 show that most of the variations in the LBP in lag 3 are accounted for by its own shocks followed by temperature, rainfall and lastly the beef producer price. In quarter 1, price shocks explain 0 percent of the average growth rate of beef production (LBP) and this share increases to about 2.18 percent in two years (quarter 8).

Furthermore, shocks in rainfall explain 0 percent of the LBP in the first quarter, in the fourth quarter (one year), the shocks result in an increase of about 2.88 percent.

Shocks in temperature explain 0 percent of the LBP in the first quarter and increase to about 11 percent in two years. These results show us that shocks to temperature account for more variation on LBP in the long run. Therefore the impact of temperature change on commercial beef production is significant.

CHAPTER SIX: SUMMARY, CONCLUSION, POLICY IMPLICATIONS AND RECOMMENDATIONS

6.0 Introduction

This chapter presents the conclusion and implications of the findings of the study. Policy recommendations drawn from the findings of the study are provided at the end of this chapter together with suggested areas of further research.

6.1 Conclusion

The main purpose of this study was to analyze the impact of climate change on commercial beef production in Botswana. Time series econometric techniques using yearly data for the period 1980-2016 was conducted to fulfill this purpose. The Phillips perron (PP) test for stationarity showed that series were stationary at levels for beef production, average annual rainfall and average annual temperature, and stationary at first difference for the beef producer prices. The Johansen Cointegration test depicts a long run relationship of one cointegrating vectors. The AR Roots test was used to ascertain the stability of the model. Residual tests were carried out as well to ensure that the data does not have a problem of autocorrelation and heteroscedasticity. The Vector Error Correction model results indicated a positive and significant relationship between the average growth rate of beef production. The climate change variables which are rainfall, temperature and drought (dummy variable) were all positive and significant and the non-climate variables beef producer prices was positive and significant while years of cattle disease outbreaks (FMD) in Botswana were positive and insignificant within the period of study.

In conclusion, the study has shown that like most developing countries climate change has an impact on beef production.

6.2 Policy Recommendations

The results of the study confirm the importance of climate change on beef production and the need to take steps to reinforce existing adaptation options and develop new ones that address climate change concerns in cattle and livestock in general in the country. This might have political implications, constraints on adaptation should be removed and better knowledge of climate change be promoted.

Furthermore, these results imply that adaptation to climate change in Botswana is important if cattle farmers are to counter the expected impacts of long term climate change. Monitoring of climate change and disseminating information to farmers on using appropriate mitigation and adaptation methods such as cross breeding to help cattle resist heat and give good quality meat and meat products, it would be an important intervention. These will encourage both short term and long term adaptations to climate change. The private sector and government should reinforce a link between research and development on how climate change affects the beef production for a better transfer of adaptation measures to farmers.

Cattle farmer's especially communal cattle farmers should be made more aware of the importance of the livestock identification and traceability system in cattle and raising their cattle according to EU market standards and improve their cattle supply to the BMC.

6.3 Limitations of the Study

The major limitation of the study was unavailability of time. The study would have gone further to examine the marginal impact of climate change on beef production in Botswana.

6.4 Recommendations for Future Research

The study focused on the impact of climate change on commercial beef production in Botswana from 1980-2016. This was done under the limiting factor such as time thus more could be done so as to improve the results.

1. It would be interesting to examine the marginal impact of climate change on beef production in Botswana.

2. It would be also interesting to examine how climate change affects different livestock species, for example goats, chickens, donkeys etc., instead of just focusing on one in Botswana.
3. To use a larger time period (i.e., 1960-2016) will take into account commercial beef production in Botswana pre independence and also at independence levels.

References

Adams, R., Hurd, B., Lenhart, S., & Leary, N. (1998). Effects of global climate change on agriculture: an interpretative review. *Climate research*, 19–30.

Adugna, A. A. (2016). Review on: Livestock Production and Global Climate Change. *Journal of Environment and Earth Science*.

BOB. (2016). *Botswana Financial Statistics.* Gaborone: Bank of Botswana.

Botswana. (2010). *Botswana Financial Statistics.* Gaborone: Bank of Botswana.

Bozzola, M., Massetti, E., Mendelsohn, R., & Capitanio, F. (2017). A Ricardian Analysis of the Impact of Climate Change on Italian Agriculture. *CMCC Research paper*.

Chaudhary, J. S. (2013). Analysis of morbidity and mortality rates in bovine in Himachal Pradesh. *Vet World*, 614-619.

Chipanshi, A., Chanda, R., &. Totolo, O. (2003). Vulnerability Assessment of the Maize and Sorghum Crops to Climate Change in Botswana. *Climatic Change*, 339-360.

Cline, W. R. (1996). The Impact of Global Warming on Agriculture. *The American Economic Review*, 1309-1311.

Dube, D. Z. (2012). An econometric analysis of the impacts of climate change on arable crop production in Botswana from 1980-2008. *Unpublished Bachelor of Arts (Social Sciences) Dissertation*.

Esterhuizen, D. (2015). *Botswana Agricultural Economic Fact Sheet (GAIN REPORT).* United States Embassy in South Africa.

Fereja, G. (2016). The Impact of climate change on livestock production and productivities in developing countries: A review. *International Journal of research-Granthaalayah*, 181-187.

Gebreegziabher, S. M. (2011). Climate Change and the Ethiopian Economy. *Environment for Development*.

Gujarati, D., & Porter, D. (2009). *Basic econometrics.* New York: McGraw-Hill.

Hollingsworth, B. (2016). The iteratile: A new measure of central tendency. *Cogent Mathematics, 3*(1).

IPCC. (2007). *IPCC, 2007: Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A.]*. Geneva, Switzerland: IPCC.

Moreki, J., Thutwa, M., Koloka,O.,Ntesang, K., & Ipatleng, T.. (2010). Utilization of smallstock package of livestock management and infrastructure development support scheme, Botswana. *Livestock Research for Rural Development,*, Vol. 22, Article #232.

Kabubo-Mariara, J. (2008). The Economic Impact of Global Warming on Livestock Husbandry in Kenya : A Ricardian analysis. *African Economic Conference on Globalization, Institutions and Economic Development of Africa*.

Kahaka, Z., Juana, J., Okrut, F., & Makepe, P. (2016). Climate change perceptions and adaptations for livestock farmers in Botswana. *International Journal of Economic issues*, 1-21.

Kebede, D. (2016). Impact of climate change on livestock productive and reproductive performance. *Livestock Research for Rural Development*.

Kgosikoma, O. E. (2006). Effects of climate variability on livestock population dynamics and community drought management in Kgalagadi , Botswana. *Thesis for the degree of Master's of science in Management of Natural Resources and Sustainable Agriculture*.

Khaqan, S.Mustafa, Z., Mukhtiar, A. & Siyal, G. (2016). Ricardian Analysis on "Climate Change and Its Impact on Livestock Husbandry" in Tehsil Faisalabad, Pakistan. *International Journal of Livestock Research*.

Kurukulasuriya, P., & Mendelsohn, R. (2008). A Ricardian analysis of the impact of climate change on African cropland. *African journal of Agriculture and resource Economics*, 1-23.

Kurukulasuriya, P., & Mendelsohn, R. (2008). A Ricardian analysis of the impact of climate change on African cropland. *AfJARE*.

Mariara, & Fredrick. (2006). The Economic impact of Climate change on Kenyan crop agriculture: a ricardian approach. *CEEPA Discussion paper No. 12, Centre for Environmental Economics and Policy in Africa*.

Masale, O. (2006). The impact of Environmental factors on sorghum output: Empirical evidence from the Pandamatenga commercial farms. *Unpublished Bachelor of Arts (Social Sciences) Dissertation*.

Mbaiwa, J. E. (2006). The effects of veterinary fences on wildlife populations in Okavango Delta, Botswana. *International Journal of Wildernes*.

McKinsey, J. a. (1998). "Technology-Climate Interactions: Was The Green Revolution in India Climate Friendly?" In: A. Dinar, R. Mendelsohn, R. Evenson, J. Parikh, A. Sanghi, K. Kumar, J.McKinsey, S. Lonergan (eds) Measuring the Impact of Climate Change on Indian Agriculture. *World Bank Technical Paper No. 402*.

Mendelsohn, Nordhaus, & Shaw. (1994). The impact of global warming on agriculture: A ricardian analysis. *American Economic Review*.

Mendelsohn, R., & Nordhaus, W. (1996). The impact of global warming on agriculture: Reply. *American Economic Review 86*, 1312-1315.

Mhozya, X. (1992). *The specifications and estimation of an econometric model of Botswana.* New York: McGraw-Hill.

Mikémina, P. (2013). Climate Change Impact on Togo's Agriculture Performance: A Ricardian Analysis Based on Time Series Data. *Ethiopian Journal of Environmental Studies and Management*.

Mincer, J. (1974). *Schooling, Experience and Earnings.* New York: Columbia University Press.

Moreki, J. & Tsopito,C. (2013). Effect of climate change on dairy production in Botswana and its suitable mitigation strategies. *Online Journal of Animal and Feed Research*, 216-221.

Nhemachena, C. (2009). Agriculture and Future Climate Dynamics in Africa: Impacts and Adaptation Options. *Centre for Environmental Economics and Policy in Africa (CEEPA)*.

Nkondze, Manyatsi, & Masuku. (2013). Factors affecting households' vulnerability to climate change in Swaziland: A case of Mpolonjeni AreaDevelopment Programme (ADP). *Journal of Agricultural studies*, 108–122.

Nordhaus, W. (2003). Reflections on the economics of climate change. *Reflections on the economics of climate change*, 11-25.

Lagat, P. & Nyangena, J. (2016). the effects of climate variability on livestock production in Kenya. *Journal of Agricultural Policy*, pp 58 - 79.

Ouedraogo, S. & Dembele, Y. (2006). Economic impact assessment of climate change on Agriculture in Burkina Faso: A ricardian approach. *CEEPA Discussion paper No. 24 ,Centre for Environmental Economics and Policy in Africa*.

Petitt, A. (2016). Women's cattle ownership in Botswana. *Doctoral Thesis*.

Rust, J., & Rust, T. (2013). Climate change and livestock production: A review with emphasis on Africa. *South African Journal of Animal Science*, 43.

Saghaian, E. D. (2018). *Beef Consumption Reduction and Climate Change Mitigation.*

Seleka, P. G. (2017). *Export Competitiveness of Botswana's Beef Industry.* Gaborone: Botswana Institute for Development Policy Analysis.

Seo, & Mendelsohn. (2008b). Measuring impacts and adaptations to climate change: A structural Ricardian model of livestock management in Africa. *Agriculture Economics*, 38:1-15.

Seo, S. N., & Mendelsohn, R. (2006a). The impact of climate change on livestock management in Africa : A Ricardian analysis. *CEEPA discussion paper No.9, Centre for Environmental Economics and Policy in Africa*.

Seo, S. N., & Mendelsohn, R. (2007). *The impact of climate change on livestock management in Africa: A structural Ricardian analysis.* United Kingdom: CEEPA.

Seo, S. N., & Mendelsohn, R. (2008a). Climate change impacts and adaptations on animal husbandry in Africa. *African Journal of Agricultural and Resource Africa*.

Siphambe, H. (1997). Earnings Differentials and Rates of Return to Education in Botswana. *PHD Thesis*.

Siphambe, H.K.,Narayana, N., Akinkugbe, O., and Sentsho, J. (2005). *Economic Development of Botswana.* Gaborone: Bay Publishing.

Steinfeld, H. G. (2006). *Livestock's long shadow: environmental.* Rome, Italy: FAO.

Stevens, C., Kennan, J., & Meyn, M. (2007). Analysis of the Economic and Social Effects of Botswana's Loss of Preferential Market Access for Beef Exports to the European Union. *Overseas Development Institute*.

Thornton. (2010). *Livestock production: recent trends, future prospects.* The Royal Society.

Thornton, P., & Herrero, M. (2008). Climate change, vulnerability and livestock keepers: challenges for poverty alleviation. *Livestock and Global Climate Change*, 21.

Thornton, P., & Herrero, M. (2008). The spatial distribution of methane emissions from African domestic ruminants to 2030. *Agriculture, Ecosystems and Environment 16*, 122-137.

Tomicha, T. L. (2018). Food and agricultural innovation pathways for. *Agricultural Systems*.

Yanfei Li, X. W. (2013). Econometric analysis of the impacts of climate change on the livestock production in Qinghai Province. *Chinese Journal of Population Resources and Environment*, 299–307.

APPENDICES

VAR Lag length selection criterion

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-21.59493	NA	5.54e-05	1.551208	1.732603	1.612242
1	31.89362	90.76844*	5.77e-06	-0.720825	0.186149*	-0.415656*
2	48.03784	23.48251	6.00e-06	-0.729566	0.902987	-0.180262
3	62.42509	17.43908	7.48e-06	-0.631823	1.726310	0.161617
4	87.67347	24.48328	5.52e-06*	-1.192332*	1.891381	-0.154756

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

VECM estimation results

Cointegrating Eq:	CointEq1			
LBP(-1)	1.000000			
LP(-1)	-0.021143			
	(0.09986)			
	[-0.21172]			
LR(-1)	2.745398			
	(0.81535)			
	[3.36714]			
LT(-1)	11.73041			
	(2.08975)			
	[5.61330]			
C	-62.04748			
Error Correction:	D(LBP)	D(LP)	D(LR)	D(LT)
CointEq1	-0.466856	0.344394	0.199104	-0.118259
	(0.11080)	(0.07183)	(0.14026)	(0.03041)
	[-4.21365]	[4.79479]	[1.41949]	[-3.88924]
D(LBP(-1))	0.204071	-0.064663	0.040047	0.139343

	(0.28091)	(0.18211)	(0.35563)	(0.07709)
	[0.72645]	[-0.35507]	[0.11261]	[1.80745]
D(LBP(-2))	-0.546754	0.180574	-0.076163	-0.086644
	(0.24204)	(0.15691)	(0.30641)	(0.06642)
	[-2.25897]	[1.15083]	[-0.24857]	[-1.30441]
D(LBP(-3))	0.217219	-0.155293	0.422923	0.061880
	(0.22422)	(0.14536)	(0.28385)	(0.06153)
	[0.96879]	[-1.06837]	[1.48995]	[1.00562]
D(LP(-1))	0.905302	-0.895790	0.014233	0.124962
	(0.36791)	(0.23851)	(0.46576)	(0.10097)
	[2.46069]	[-3.75584]	[0.03056]	[1.23764]
D(LP(-2))	-0.096749	-0.076017	0.048669	-0.090601
	(0.15587)	(0.10105)	(0.19732)	(0.04278)
	[-0.62072]	[-0.75230]	[0.24665]	[-2.11803]
D(LP(-3))	0.020678	0.090299	0.262501	-0.028639
	(0.15273)	(0.09901)	(0.19335)	(0.04191)
	[0.13539]	[0.91202]	[1.35766]	[-0.68328]
D(LR(-1))	1.154990	-0.951611	-1.269373	0.249822
	(0.33333)	(0.21609)	(0.42199)	(0.09148)
	[3.46496]	[-4.40371]	[-3.00808]	[2.73091]
D(LR(-2))	0.896478	-0.730386	-0.823842	0.137084
	(0.29851)	(0.19352)	(0.37790)	(0.08192)
	[3.00321]	[-3.77431]	[-2.18007]	[1.67336]

D(LR(-3))	0.724645	-0.425529	-0.396756	0.142536
	(0.20693)	(0.13415)	(0.26197)	(0.05679)
	[3.50180]	[-3.17200]	[-1.51450]	[2.50985]
D(LT(-1))	4.697037	-4.230487	-2.236129	0.227208
	(1.23838)	(0.80282)	(1.56775)	(0.33986)
	[3.79288]	[-5.26956]	[-1.42633]	[0.66853]
D(LT(-2))	3.436573	-3.453077	-0.107154	0.192766
	(1.10325)	(0.71521)	(1.39667)	(0.30277)
	[3.11495]	[-4.82804]	[-0.07672]	[0.63667]
D(LT(-3))	1.818442	-1.568290	0.753631	0.130772
	(0.76048)	(0.49300)	(0.96274)	(0.20870)
	[2.39118]	[-3.18110]	[0.78280]	[0.62659]
C	-0.315848	0.320130	-0.048908	-0.011933
	(0.09524)	(0.06175)	(0.12058)	(0.02614)
	[-3.31617]	[5.18470]	[-0.40562]	[-0.45653]
OD	0.046777	0.055039	-0.034458	-0.040624
	(0.12469)	(0.08083)	(0.15785)	(0.03422)
	[0.37515]	[0.68089]	[-0.21829]	[-1.18716]
D01	0.297325	-0.240696	0.112231	0.033028
	(0.11773)	(0.07632)	(0.14904)	(0.03231)
	[2.52554]	[-3.15378]	[0.75303]	[1.02227]
R-squared	0.701343	0.829938	0.679010	0.797290
Adj. R-squared	0.437823	0.679884	0.395783	0.618429
Sum sq. resids	1.327355	0.557841	2.127301	0.099971

S.E. equation	0.279428	0.181147	0.353745	0.076686
F-statistic	2.661436	5.530915	2.397405	4.457587
Log likelihood	6.194792	20.49815	-1.587689	48.86476
Akaike AIC	0.594255	-0.272615	1.065921	-1.991804
Schwarz SC	1.319834	0.452965	1.791500	-1.266224
Mean dependent	-0.021495	0.089217	0.005103	0.000416
S.D. dependent	0.372677	0.320167	0.455086	0.124144
Determinant resid covariance (dof adj.)		8.73E-07		
Determinant resid covariance		6.15E-08		
Log likelihood		86.67071		
Akaike information criterion		-1.131558		
Schwarz criterion		1.952154		