UNIVERSITY OF BOTSWANA

Faculty of Social Sciences

Department of Economics

THE POTENTIAL BENEFITS OF LIVESTOCK PRODUCTIVITY INCREASE TO BOTSWANA ECONOMY- The Recursive Dynamic Computable General Equilibrium Modelling Application

By

KOKETSO GATSOSWE

STUDENT NUMBER: 201703555

A dissertation submitted to the department of Economics in Partial fulfillment of the requirements for the degree of Master of Arts in Economics

September, 2020

CERTIFICATION

This dissertation has been examined and approved as meeting the requirements for the partial fulfilment of MA (Economics) Degree.

Dr J.B. Tlhalefang　　　　　　　　　　　　　　　　　　　　Date

(Supervisor)

(Head of Department)　　　　　　　　　　　　　　　　　　　Date

DECLARATION

The work contained in this dissertation was completed by the author at the University of Botswana. It is an original work by the author except where due reference is made and neither has been nor will be submitted for award of any other University.

Gatsoswe Koketso

Signature: ______________________ Date: _________________________

Table of Contents

DEDICATION

This dissertation is dedicated to my grandmother Mrs Gotshwaraganye Lydia Gatsoswe who loves and nurtures me to the best of her ability. Thank you for believing in me.

ACKNOWLEDGEMENTS

It has been a struggle finishing this work; there has been great support from different individuals and institutions without which it wouldn‘t have been possible. It is therefore essential to recognize their contribution. My sincere gratitude is expressed to the following persons and institutions:

My deepest respect and most sincere gratitude to my supervisor Dr J.B Tlhalefang for introducing me to the use of SAM and CGE modelling, for excellent guidance, support and patience throughout this dissertation. My co-supervisor Mr Rathedi for the valuable comments and advice on this dissertation proposal.

My deepest love and appreciation goes to my pastor Apostle Kobamo Boago Gofhamodimo and Spiritual family at Divine Favour Christian Ministries who have seen me throughout my academic endeavors; their moral and spiritual support has made me through.

My family and relatives, you are my pillar of strength. Your unfailing love, support and encouragement enabled me to go on the heights.

My thanks and appreciation also go to my colleagues for the time we spent together. The love and care you gave me is forever treasured. I wish you well in all your future endeavors.

I would like to also express my sincere gratitude to the University Of Botswana Foundation-Northern Trust First in the Family for awarding me a Masters scholarship tenable at the University of Botswana.

Above all, all glory is to God. True wisdom and power are found in Him; counsel and understanding are His.

ABSTRACT

To determine the the potential impact of livestock productivity increase on Botswana economic growth; poverty and income inequality reduction, food security and; employment, the study utilized the Thurlow (2004) South African recursive dynamic CGE model. The model is an extension of the static standard CGE model developed by Lofgren et al., (2002) under the auspices of the International Food Policy Research Institute (IFPRI). The model was parameterized and initialized to the modified version of the 2011 Botswana economy EcoMod SAM with behavioural parameters and information set on exogenous variables and parameters of the dynamic sub-model. It was then solved in GAMS as a mixed complimentary problem (MCP) with PATH solver. The solution results were then exported from GAMS to excel spreadsheet for formal presentation of selected variables relevant to the study objectives. Three of simulations were undertaken, namely; the baseline scenario (referred to as the reference or business-as-usual (BAU) scenario); the counterfactual scenario and; the sensitivity tests simulations. Given an average Botswana economy growth rate of 4.3 percent, the baseline scenario gave an average annual increase of 4.37 percent in total GDP showing a close similitude of the model real GDP growth rates. This indicates that the model generates the BAU scenario that realistically approximates the evolution of the Botswana economy during eight-year time horizon, 2011-2019. The counterfactual results were analysed by a paired comparison of the values of selected indicators for the reference scenario. A 5 percent increase in Hick-neutral technological progress in livestock sector translates to a 0.40 percent rise in in the aggregate welfare of the Botswana economy. The livestock productivity increase is therefore capable of increasing the level of economic activity. Private consumption- used synonymously to household final consumption expenditure, increased by 0.36 percent demonstrating the households' participation and gain from livestock GDP growth hence increase in food security and poverty reduction. Complimentary to 0.76 percent increase in investment, this increase in consumption due to *price reductions improved food security (food availability and accessibility to the low income households with high food consumption shares) and their overall welfare. Moreover, the 5 percent increase in the livestock productivity caused an employment increase in all the labour skill types. The unskilled labour type skill increased the most and consequently leading increase in rural households' income (as is agriculture specific an most of the rural people in Botswana generally have received no special training and has few specific skills, thus unskilled). The sensitivity analyses results showed both the quantitative and the qualitative results to be generally robust.*

These findings recommends that improve-livestock policy is a plausible and appealing choice for policy makers in promoting the country's economic growth, reducing poverty, income inequality and rural unemployment. It is therefore suggested that, in implementing the improve-livestock policy, there is need to capture in the specification of the livestock stock-flow linkages and recognize the livestock capital as a factor of production in production sectors. This is to trace the livestock production system external shocks to the economic flows and capture livestock capital vital role in other economic sectors particularly other agriculture and manufacturing.

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

ACET	The African Center for Economic Transformation
BITC	Botswana Investment Trade Centre
BOPA	Botswana Press Agency
BWP	Botswana Pula Currency
CAADP	Comprehensive African Agriculture Development Programme
CGE	Computable General Equilibrium
FAO	Food and Agriculture Organization
FMD	Foot and Mouse Disease
GAMS	General Algebraic Modelling System
GDP	Gross Domestic Product
GTAP	Global Trade Analysis Project
HIV/AIDS	Human Immunodeficiency Virus/ Acquired Immuno Deficiency Syndromme
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
LIMID	Livestock Management and Infrastructure Development
MFED	Ministry of Finance and Economic Development
MTR	Mass Transit Railway
NDP	National Development Plan
SAM	Social Accounting Matrix

CHAPTER 1

BACKGROUND

1.1 Introduction

Livestock production is an important agricultural activity in most developing countries. This is especially the case in the arid and semi-arid African countries (Girma and Abebaw, 2012). It is advantageous over other sub-agricultural sectors. These are neatly summarised by, among the others, Girma and Abebaw (2012). Firstly, it is a source of national food supply and food security, especially to the rural poor as it is a source of meat, milk, hide, wool, etc. Secondly, it is a source of income, particularly to the smallholders. Thirdly, it provides manure and animal draught power to the arable agriculture. Fourthly, it is an inflation free store of value. Lastly, it is a source of financial capital (cash, saving, credit, insurance, gifts, and remittance) and social capital (traditions, wealth, prestige, identity, respect, festivity, bride-price or dowry). Moreover, as the International Fund for Agricultural Development (IFAD, 2010) noted, the livestock sector promotes gender balance. The argument is that the livestock production systems offer the potential for introducing a wide range of project activities relating to gender mainstreaming. In the same vein, Girma and Abebaw (2012) concluded that the livestock sector supports the livelihoods of large proportion of households and has important role on value addition as well as on insuring national food security.

However, in developing countries, the livestock sector's contribution to the economy is typically minimal. For example, in Botswana, beef as the prominent livestock industry contributes about 57% of agricultural value added (Bahta and Malope 2014) and in Zambia livestock contributes 7 percent to total GDP. This is in spite of the large numbers of livestock kept. For instance, there was 1, 360, 467 heads of cattle in Botswana in 2015 (Statistics Botswana, 2018) and 3,714,667 heads of cattle in Zambia in 2018 (Zambia Central Statistical Office, 2019). The factors contributing to the livestock sector's relatively low contribution to the economy are, inter alia: low livestock growth rates, high mortality rates, low production and reproductive rates, low off-take rates and poor quality of the final products from the industry. Beyond these, the measurement of the contribution of the livestock sector as by its share in GDP neglects its other values such as serving as an inflation free store of value and social capital. Such contributions are not captured in the national accounts. An obvious implication of this is that the importance of the livestock sector in the economy is largely under-stated. Both policymakers' and researchers' neglect of the sector contribution is also an important causal factor to the low contribution of the livestock sub-sector in the economy (Engida et al., 2015). Researchers' neglect of the livestock sector has been attributed to methodological reasons (Engida et al. 2015).

Cognizant the fundamental role the livestock sector plays, if not in terms of the sub-sector's economic size, but as an element of development strategy (MTR, 2019), the Botswana livestock sector has also received much attention. Through the successive national development plans (NDPs), the NDP10 identified insufficient infrastructure and low productivity levels for both the livestock and crop sub-sectors as a challenge limiting the agricultural sector production capacity. Following the latter, Botswana NDP11, vision 2036 and the 2020/21 budget developed policy reforms and programmes seeking to build on the potential of livestock production. Furthermore, amidst the Covid-19, Botswana government, views the agricultural sector development as one of the possible alternatives to help the nation become self-reliant (BOPA, 2020).

While agriculture is found to continue to be an effective engine for economic growth in developing countries, it does not always follow that it will lead to such growth. An increase in agricultural productivity can have a variety of impact with different consequences on output, profit and employment. First, an increase in agricultural productivity can reduce the quantity of inputs needed. This will lead decline in producer prices hence low production costs. The fall in production cost raises profits, but output may not be affected and employment could be reduced. Secondly, increase in agricultural productivity may raise yields, output and probably employment will increase, but profits may not necessarily increase. The increase in output due to productivity improvement may also cause a decline in producer prices hence low production costs. This consequently raises employment through increase in demand for both labour and capital. Increased output generates the surplus goods that directly satisfy the basic human needs. These surplus goods provide better caloric nutrient intake by the poor, food availability, food price stability, and poverty reduction (Timmer, 1995). Thirdly, increase in agricultural productivity may raise labour productivity. This is a result of the rise in the marginal product of labour. With increased labour per unit of output, wage rates will increase but possibly at the expense of the labor quantity employed and profits with indeterminate output effects. This leads to unemployment.

However, with the evolution of development theories, agriculture bared two extreme views. Firstly, as a reservoir of unemployed or underemployed labor, with low incomes and living standards which was to be moved by non-agricultural sector economic growth. The alternative extreme view is that the agricultural sector itself must generate the growth that will eventually release labor and other resources. Following Mellor's seminal work on agriculture on the road to industrialization and Adelman's agricultural development led industrialization, Schultz-Jorgenson described these views to be determined by the two economy states. The first state is where the economy has reached satiation in terms of the domestic food production. The second state is about the economy which is yet to reach satiation in terms of the domestic food production. In respect to Botswana livestock, the economy is at a stage yet to reach satiation in terms of the domestic food production since insufficient infrastructure and low productivity levels for agricultural sector are identified as challenges limiting the agricultural sector production capacity in Botswana.

Botswana-a higher middle income country, has its economy mainly diamond and public-sector driven. The country income gains, particularly from diamond production, do not get distributed as evenly as from other sectors such as agriculture hence not contributing much to poverty alleviation and food security, (FAO, 2014). The country strives for economic diversification in efforts to reduce its high dependence on diamonds. The agricultural sector is one other potential candidate for diversification though has not performed as well as the rest of the economy. Coupled with arable sub-sector traditional predominance, the Botswana semi-arid climate makes crop production risky to practice. However, with livestock ability to stand unstable and hazardous climate conditions, it is found to have potential to grow. Additionally, most of the rural Batswana population living in abject poverty derive at least most or in part of their food and income from livestock. Abreast livestock revolution, low livestock productivity with growth in livestock products consumption implies increase in their net imports hence a substantial strain on the balance of trade and the exchange rate consequently leading to inflationary pressures. Cognizant the latter, Bahta et al., (2018) viewed livestock sector improvement as one of the potential ways to increase rural household incomes, create sustainable jobs and investment opportunities for the rural population and drive economic diversification away from a mineral-dependent economy. In Botswana, although beef dominates the agricultural exports, there exists room for expansion as much attention is currently placed on the production of raw beef products, including by-products, (Seleka, 2005). On the other hand, Bahta et al, (2015) reported importation of small stock (goat) meat which is the main source of protein to most households in the country ascribing to its low productivity domestically. This is in spite the government continued efforts through her successive NDP's, vision 2036 and budget plans. It is therefore that, increasing livestock productivity is not only pressing, but also urgently necessary.

1.2 Problem Statement

Available forecasts, fostered by globalization, integrated value chains, rapid technological and institutional innovations, and environmental constraints point to a rapid growth in global demand for animal products, particularly in most developing countries. Some analysts and researchers including Lapar et al. (2003) and Delgado et al. (1999) have termed it the livestock revolution. Lubungu et al. (2012) forecasts underscore that the increase in demand of livestock products and by-products would stem from growth in human population, in urbanization and in income. Correspondingly, most of the world rural population living in abject poverty derive at least most or in part of their food and income from livestock. The livestock sector therefore requires improvement to meet the increased demand for livestock and livestock products.

In Botswana, the semi-arid climate makes crop production risky to practice leading to low supply of food grain in country. Crop production is predominantly traditional-primarily uses unsophisticated production techniques and subsistence-oriented. This exacerbates the poor performance of the sub sector. The arable sector therefore found to be at a stage where its contribution to the country's food security is tremendously daunting. Food grain demands are met through imports. These arable agricultural challenges represent an added challenge to the fight against poverty and high-income inequality rates in the country. Nonetheless, despite the Botswana livestock poor performance, as far as environment is concerned, livestock production can be practiced under unstable and hazardous conditions, and further complicated by bush encroachment and occasionally desertification, (Mamabolo and Webb, 2005).

With majority of rural Batswana depending on agriculture for food, income and informal employment, efforts to promote agriculture need to be continued. Owing to the agricultural sector's poor performance, most Batswana migrated from rural places (agriculture-centred) to urban (industrialized/mineral exploration) areas to seek employment. The number of people producing food in the agricultural sector was reduced. The healthy young people and men moved from rural places to urban areas, leaving behind the women, old, sick and the dependent in charge of the farms. This interactions increased sophistication of agricultural markets (and value chains) which excludes traditional smallholders, who are poorly equipped to meet the demanding product specifications and timeliness of delivery required by expanding supermarkets, (Meijerink and Roza. 2007). An imbalance of people producing food in the agricultural sector and in the non-agricultural sector resulted in food shortage due to lowered production. This consequently triggers a rise in food prices, urban wage rates and subsequently choking off industrial development. Increases in food prices would raise the cost of living, especially for low income households with high food consumption shares since these rural people are usually consumers. This food price increase therefore concerns them most. It is therefore that, without rising farm productivity, the transfer of labour and capital from agriculture leads to falling agricultural output, rising food prices and growing poverty (Johnston and Mellor 1961).

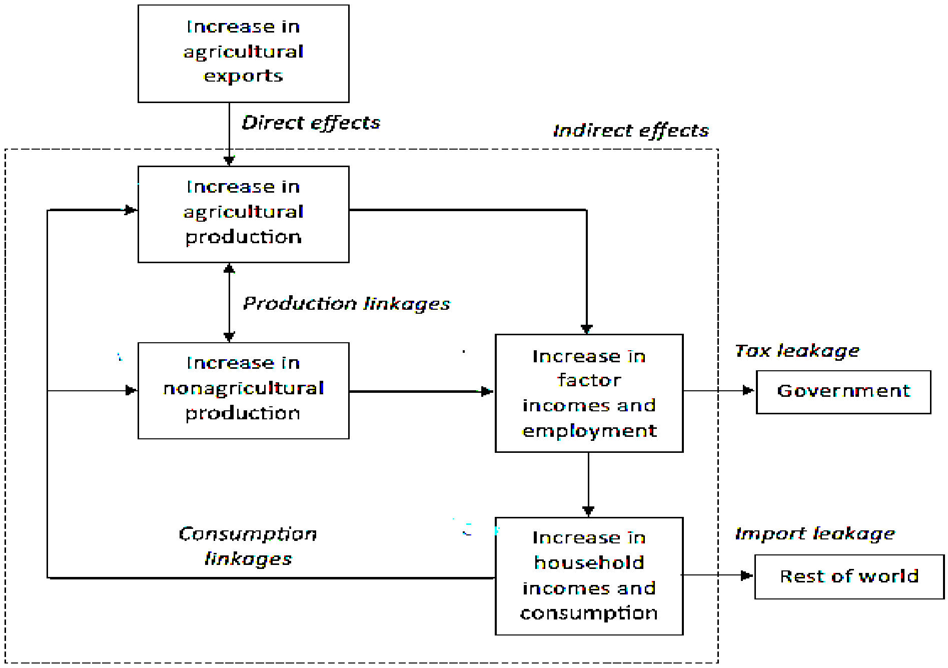
Furthermore, for agriculture's inter-sectoral interactions and micro-macro relations, it provides key roles in the development strategy. These are as summarised by ACET, (2016) and Breisinger et al., (2011). Firstly, agriculture is a provider of capital for other sectors. For example, transforming agricultural sector helps spur manufacturing sector growth through provision of cheap raw materials for processing. Secondly, it helps moderate food price inflation and thereby industrial wage increases which help keep manufacturing internationally competitive. Third, it provides an expanded domestic market arising from higher rural incomes for manufactured goods. Fourth, it is a source of labour to other sectors of the economy. Lastly, it provides higher levels of foreign exchange earnings and fiscal revenues to help finance imported inputs and public goods necessary for manufacturing and other sectors of the economy.

With agricultural productivity increase driven by the demand (rural households consumer and farmers production factor demands) and supply (agricultural goods without rising prices) incentives (Subramaniam and Reed, 2009), livestock productivity increase can help Botswana achieve food security, economic-wide growth, employment; income distribution, economic diversification and alleviate poverty. The Botswana beef industry has room for expansion as much attention is currently placed on production of raw beef products and by-products. Analogously, small stock shows an untapped potential, hence increasing livestock productivity remains an alternative in promoting the country's export diversification efforts to stimulate employment creation domestically and improve the country's balance of payments through generating foreign exchange.

As depicted figure 1.1 below, it can be seen that changes in exogenous shock to the agricultural sector- increasing livestock productivity, increases agricultural output. An increase in agricultural production, thus large supply of food, keeps down the relative prices of agricultural outputs. The fall in relative price of food reduces production costs which subsequently lead to a substantial increase in the households' incomes and consumption as factor owners. This is in cognizant that households now save more and spend more, stimulating growth and investment in other sectors. With increased output and low production costs, profits increases and factor demands (labour wages and capital rents) also increases hence employment. For exported commodities, foreign exchange earnings and fiscal revenue increases helping to finance imported inputs and public goods. Lower food prices, stimulated by technological change in agriculture, maintain low real wages in industrial sectors and thus foster investment and structural transformation, (Diao et al., 2006). Through agricultural taxes, both direct and indirect, agriculture provides tax revenues to government.

From these economic linkages, changes in exogenous shock to the agricultural sector, particularly livestock, will translate into production and income changes, as seen in example of increase in exogenous demand shock of increased agricultural export demand in figure 1.1 below.

Figure 1.1: Circular Flow if Income from Increased Agricultural Export Demand



Source; Breisinger et al., (2010).

It goes without saying that, in the face of increasing livestock productivity in the country as a way to diversifying the economy, this gives a rise to questions that; how large are the livestock prospective linkages to other sectors; what is the growth and poverty reduction potential of the livestock industry; and which policy interventions are capable of unlocking the industry growth potential. This therefore calls for the use of the methodology that will capture both the indirect and direct livestock links and show how the benefits of livestock productivity increase are dampened throughout the economy, thus hence use of computable general equilibrium (CGE) model in the study.

1.3 Objectives—broad and specific

The broad objective of the present study is to assess the improve-livestock-productivity policy on economic development in Botswana. The specific objectives of this study are to determine the potential impact of the increase in the livestock productivity on:

i. economic-wide growth;

ii. Employment;

iii. income distribution; and,

iv. economic diversification; and,

v. Draw policy implications.

1.4 Analytical Framework

The computable general equilibrium (CGE) modelling approach is used to explore the impact of the livestock-productivity improvement policy on economic development in Botswana. A CGE model- an economy-wide model that incorporates the fundamental general equilibrium links among production structure, incomes of various groups and the pattern of demand, (Dervis et al., 1982), has proven to be a more wield tool in evaluation of economic policies (Hosoe et al. 2010). As Shoven and Whalley (1992) pointed out, the CGE model has advantages of having strong links with economic theory in that behaviours of economic agents are based on constrained optimization. According to Rossouw (2004), this modelling framework particularly suited for answering the "what if" questions. For example, what would happen to the economy if productivity in agriculture increased? It has been applied in Botswana by some researchers including Olsson and Ohlund (2004) to assess the impact of diamond dependence and HIV/AIDS on the economy, Tlhalefang and Mangadi (2006) to evaluate the effects of an increase in Hicks-neutral technical progress in agriculture sector on the economy. This is important as the present study also deals with a "what if" question. The model will enable answer the key question of what would be the potential impact of an increase in livestock productivity on the economy.

1.5 Significance of the Research

Despite some significant decrease in poverty rates, the poverty, income inequality rate and unemployment remain to be high. Further, agricultural sector having never performed as much as the rest of the economy; it is still incumbent to promote the sector as majority of the rural Batswana households depend on agriculture for food and informal self-employment. It is for this reason that, with the Botswana arable agriculture found to be at a stage where its contribution to the country's food security is tremendously daunting, this study use recursive dynamic CGE to assess the improve-livestock-productivity policy on economic development in Botswana and add value to the already existing literature. With the dynamic CGE models have been applied in Botswana, the models were not livestock focused. They are instructive in terms of modelling of the dynamics and construction of the simulations. The study will provide recommendations that will assist policy makers and other stakeholders in making informed long-term decisions.

1.6 Organization of the Study

The subsequent chapters this thesis proceeds as follows; chapter two presents a review of the functioning, economic development and structure of the economy of Botswana. The chapter reviews Botswana economy form 1966, the year the country gained independence with much focus on agriculture- a sector of interest for our study. It highlighted the economic performance, external trade and performance of the livestock sector in the country. This provided information informing the development of the employed model, design of simulations and subsequently interpretation of the simulation results. Chapter 3 presents both the theoretical and empirical literature review on livestock sector development role to economic growth. This review of literature sheds some light on the livestock productivity increase and subsequently instructs the design of model. The empirical literature review part gives insights on different methodological tools used to analyse the livestock development role to economic growth.

Chapter 4 presents discussions on background and important aspects on CGE modelling and also explores the dual functioning of a SAM as database and as an approach to modelling. Chapter 5 now narrows onto the model implementation which entails domesticating the model to capture the main features of the Botswana economy. In this chapter, simulation designs are also explained. Chapter 6 reports the model simulations main findings by comparing the reference scenario (model without shock) to the counterfactual scenario (model with an economic shock) results between the parallel run models. The last chapter 7 gives a concluding discussion of the implications of the results. The chapter also provides recommendations for further research. The addendum contains the lists of model variables and parameters and their descriptions, model equations, the list of SAM accounts and the model limitations.

CHAPTER 2

THE BOTSWANA ECONOMY

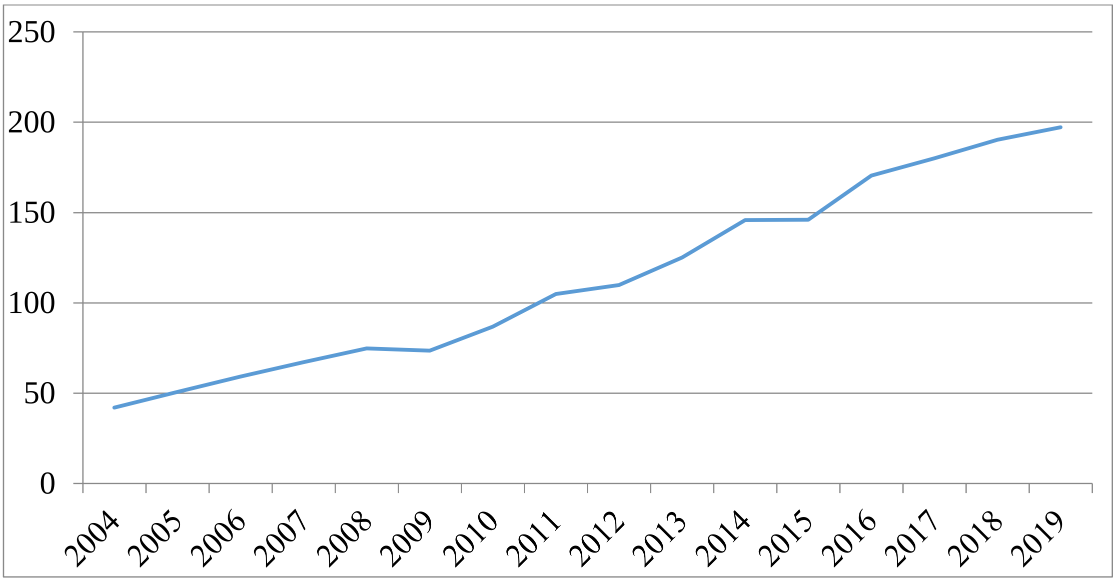
2.1 Introduction

The purpose of this chapter is to review the economy of Botswana to understand how it functions. This information subsequently instructs the development of the CGE model used in the study, design of policy simulations and interpretation of the simulation results. The chapter is structured as follows: Section 2.2 gives the economy structure and performance of Botswana; 2.3 Trade sector; 2.4 the livestock sector and finally section 2.5 concludes the chapter and introduce the following chapter.

2.2 Economic Performance and Structure of Botswana Economy

Botswana’s economy at independence in 1966 was agriculture-based and least-developed. Agriculture contributed about 40% of gross domestic product (GDP) and government relied on grants mainly from Britain to finance recurrent expenditure and foreign aid for investments. However, the country became one of the sustained world’s fastest growing economies after the discovery and successful exploitation of diamonds in 1967 (see figure 2.1 below). It transitioned from low income country to a higher middle-income country. Not only has diamonds been pivotal in the country’s economic transformation, but also the country’s strong democratic institutions, prudent economic management, and the sustainable use of proceeds from diamond production to build productive physical and human capital (NDP11).

Figure 2.1: Botswana GDP Trend (in BWP Billion)



Source; Authors Compilation Statistics Botswana Data (2020)

Despite the country's good economic growth, Botswana is still experiencing challenges of rural poverty (proportion of people living below the poverty datum line accounting for 16.3%), inequality (Gini Coefficient of 0.522), food insecurity, and high unemployment rates (17.6%), (Statistics Botswana, 2018).

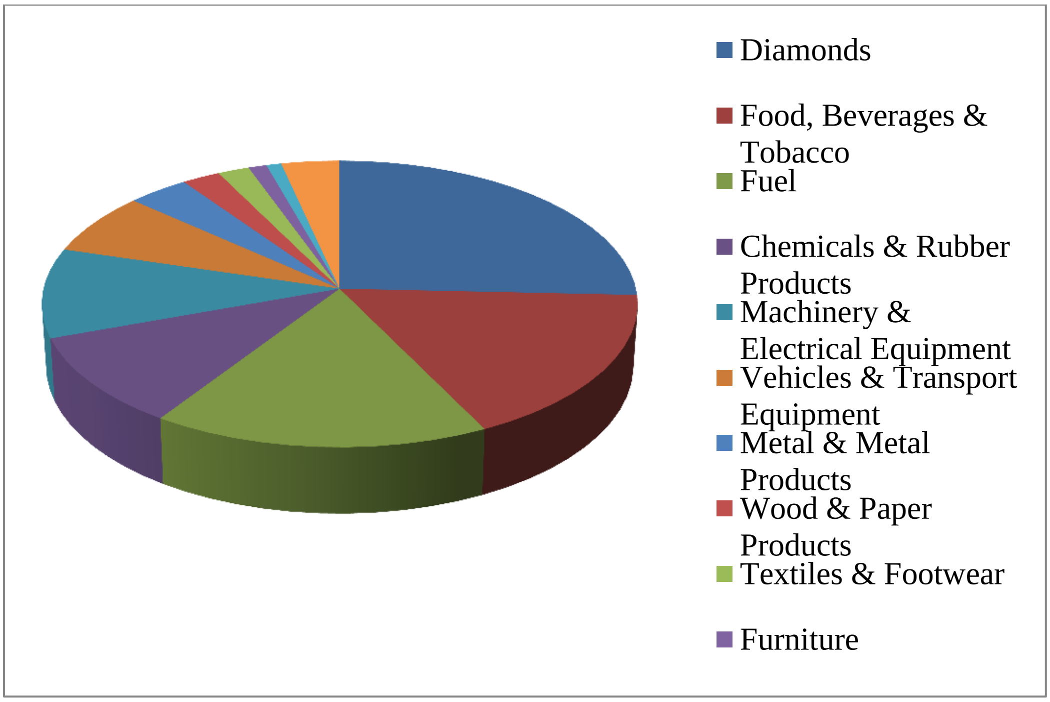
In 2019, Botswana real GDP rose by 3.0 percent as compared to the 4.5 percent in 2018. This increase is attributed to the significant growth in real value added of Water & Electricity, Finance & Business Services and Transport & Communications industries. However the major contributors to GDP in terms gross value added are Trade, Hotels &Restaurants contributing 19.7 percent, followed by mining (15.2 percent), then the general government (14.7 percent) and finance and business service (14.5 percent). The agricultural sector and water and electricity are the smallest sectors in terms of gross value added contribution to GDP at 1.9 percent and 1.0 percent respectively. Other sectors construction, Transport& Communication, manufacturing, and Social& Personal Services contributes 6.8 percent, 6.1 percent, 5.2 percent and 5.6 percent respectively. With the government's efforts to diversify the economy away from diamonds, the increase in value added in sectors like Finance and

Business Services industry which was mainly due to increase in Business Services(6.7), Real Estate(6.6) and Finance (6.5) shows success progress.

Of the GDP components by expenditure type, the government and household consumption increased by 4.3 and 3.6 percent respectively while the Gross Fixed Capital Formation grew by 4.5 percent. Botswana as a small open economy, from the external sector, its real exports in 2019 decreased by 16.6 percent while imports increased by 6.7 percent in the same year. The diamonds as a major export commodity experienced a significant decline of 32.7 percent (Statistics Botswana, 2020).

In December 2019, Botswana imports were valued at BWP P6, 233.2 million while the exports were valued at BWP5, 772.9 million. Statistics Botswana continues to reveal that the principal import commodities were Diamonds; Food, Beverages & Tobacco and Fuel with contributions. Their percentage share contributions to total imports are as shown in figure 3 below.

Figure 2.2: Principal Imports Composition- December 2019

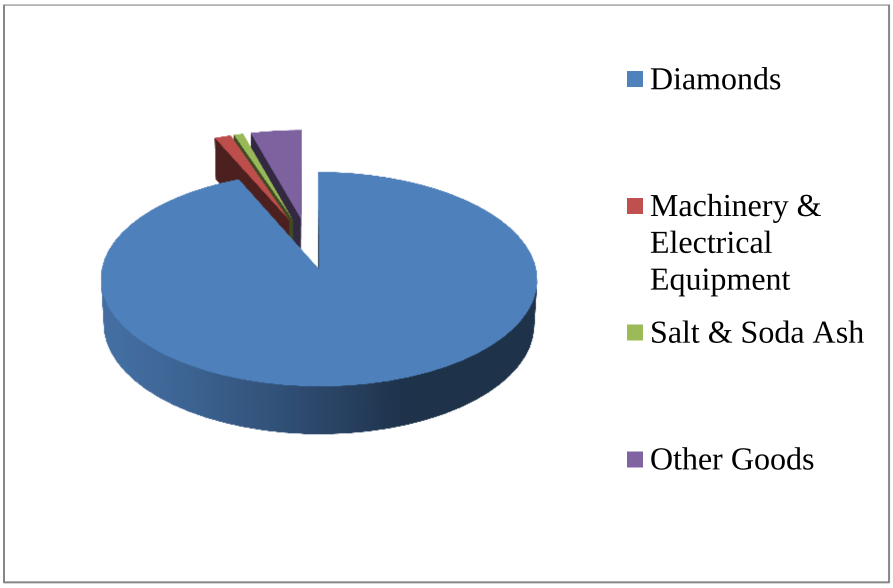


Source: Statistics Botswana (2020)

Of the total imports, the SACU region which supplied 71.4 percent, from which South Africa accounted for 64.4 percent followed by Namibia with 6.5 percent. Other main major import partners include Asia accounting for 9.1 percent, European Union contributing 8.8 percent and Canada contributing 4.8 percent while USA contributed 1.0 percent of the total imports into Botswana.

On the export side, the major export commodities include diamonds accounting for 93.5 percent of total exports, machinery& electrical equipment contributed 1.4 percent. Figure 4 shows these exports share contributions. However, in June 2019, the meat and meat products contributed 1.8 percent of the total value of exports.

Figure 2.3: Principal Exports Composition- December 2019



Source: Statistics Botswana (2020)

Botswana’s major export trading partners included India with a share of 30.8 percent, Belgium accounting for 20.0 percent share. Other trading exports partner was the United Arab Emirates contributing 16.9 percent of total exports.

2.3 The Livestock Sector

The livestock sector is composed of traditional (communal) and commercial farming system. The traditional system is predominant with 88% of cattle and 98% of small stock, (Bahta et al., 2015). The communal system of production is found in the communal/ tribal land areas where animals graze in open rangelands with no defined property rights to grazing resources, and few fences. Conversely, the commercial system of keeping livestock is found in the freehold and leased land, and is characterized by fenced farms and owner's exclusive rights to grazing resources. The main livestock species with the livestock sector are cattle, goats and sheep. Table 1 below shows these three livestock species productivity indicators trends between two censuses, 2004 and 2015.

Table 2.1: Livestock Productivity Indicators Trends (Between 2004&2015)

	POPULATION			BIRTH RATE (%)			MORTALITY RATE (%)			OFF-TAKE RATE (%)		
	2004	2015	% CHANGE	2004	2015	% CHANGE	2004	2015	% CHANGE	2004	2015	% CHANGE
CATTLE	2155000	1744000	-19	53.9	56.7	2.8	11.9	6.3	-5.6	8.4	7.7	-0.7
GOATS	1550000	1205000	-22	48.0	43.4	-4.6	21.9	16.7	-5.2	7.3	7.2	-0.1
SHEEP	244000	242000	-1	39.2	36.4	-2.8	19.4	11.8	-7.6	7.2	6.6	-0.6

Source: Author's Complication from Agricultural Census Report 2015

Livestock statistics showed cattle, goats and sheep populations to have decreased by 19 percent, 22 percent and 1 percent respectively. Cattle birth rate increased while it mortality and offtake rates declined. Correspondingly, goats and sheep birth, mortality and offtake rates all dropped. All livestock recorded a decline in death rates. About 71.1% of Batswana farmers keep goats, 62.0% cattle and 20.4% sheep associated with government LIMID programme, (Statistics Botswana, 2018). These high mortalities, low off take and low births are found to be common in communal farming and are attributed to poor livestock management and husbandry practices. As shown in table 2 below, these mortalities are most associated with diseases. Unlike with the arable farming, drought comes third after predators thence drought is not a major threat to the livestock sector mortality.

Table 2.2: Livestock Mortality Causes in the Traditional Sector (%)

Cause/Livestock species	Diseases	Parasites	Accidents	Predators	Drought	Others
Cattle						
Calves	53	1	2	23	15	5
Cattle	59	2	4	11	21	4
Goats						
Kids	62	1	1.5	19	10	5
Goats	61	1	3	2	8	6
Sheep						
Lambs	57	1	2	24	9	7
Sheep	48	8	3	23	10	9

Source: 2015 Agricultural Census Report

The contributing factor to livestock sector poor performance is found to be farmers' reluctance to adopt modern husbandry practices such as use of supplementary feeds, artificial insemination as breeding method (Malope et al., 2018). Malope et al noted a decreased amount of land for grazing as some of it has been allocated to other uses like, residential, commercial and industrial uses and arable agriculture. However, improved management, for example selling younger male animals which will release the grazing land to the breeding herd can help produce more output using the same amount of land (Malope et al., 2018)

With the European Union (EU) imposed restriction on Botswana beef exports, this has added compliance costs to the already existed EU standards costs such as binding regulations for animal welfare. Botswana, through Botswana Meat commission (BMC), a state trading monopoly agency, established in 1966, slaughters and market beef at set annual EU Cotonou

Agreement quota of 18, 916 tons/annum that offers Botswana a preferential access to EU markets. The EU restrictions require that beef exports be boneless meat cuts with annual European Commission (EC) inspections. Surrounding the Foot and Mouth Disease (FMD) pandemic, Botswana is demarcated into 17 veterinary zones; with Selebi-Phikwe region (zone 7) being a vaccinated zone while the zones 6-covering Francistown, 8- Serowe and 9-covering Palapye regions are buffer zones. In ensuring full transparency from the birth to the slaughtering and marketing of the beef, the Government of Botswana introduced the "Livestock Identification Traceback System" (LITS). Beef exports from zone 7 are prohibited to the EU market. The meat is therefore sold to the domestic market or exported to South Africa. However, cattle from this red zone are quarantined for 21 days before slaughter then their deboned meat is frozen for another 21 days before sale.

2.4 Botswana Government Policy on Livestock Production

Due to the fundamental role the livestock sector plays, if not in terms of the sub-sector's economic size, but as an element of development strategy (MTR, 2019), the Botswana livestock sector has received much attention. The country established a number of programmes and projects targeted to enhance policies which seek to build on the potential of the livestock sector. Through the successive national development plans (NDPs), the NDP10 identified insufficient infrastructure and low productivity levels for both the livestock and crop sub-sectors as a challenge limiting the agricultural sector production capacity. The NDP11 thence developed policy reforms and programmes directed to curb the NDP10 challenges- thus improve the livestock sector. The policy reforms and programmes entail; the training of farmers, herdsmen and extension officers on beef productivity in cooperation with the New Zealand Government-expected to improve the beef sector; privatization of the Lobatse and Francistown BMC abattoirs and franchise of the Maun BMC abattoir- intended to introduce competition and promote efficiency and productivity in the beef industry, thereby increasing income-earning potential for cattle farmers; and regulation of the envisaged areas of the cattle and beef value chain, namely, abattoirs; cattle traders; live cattle import and export; consumer protection and public education; and compliance with national, EU and other external market requirements (NDP11). In support of the latter, the vision 2036 sets to support the agricultural productivity and competitiveness. The vision asserts that the agricultural sector improvement could not only bring about a direct positive impact on the livelihoods of many rural Batswana through provision of food and creation of employment but also contribute to government revenue generation and export earnings (Government of Botswana, 2016). Additionally, the 2020/21 budget reveals the Government continued efforts to build on the potential of livestock production to achieve food security and alleviate poverty at household level (MoFED, 2020). Amidst the Covid-19, world pandemic which threatens the world food security, the Botswana government, as one of its recovery plans in reviving the economy from Covid-19 effects, views the agricultural sector development as one of the possible alternatives to help the nation become self-reliant (BOPA, 2020).

2.5 Summary of the Chapter

This chapter reviewed the selected aspects of Botswana economy which provided the information that subsequently instructs the design of the CGE model for this study. The main findings pertaining to the Botswana economy operation is that, the economy is mainly driven by the diamond mining sector and public service sector. The profits accruing from this sector therein to channelled to developing lagging economic sectors mainly through the government's investment in infrastructure and human capital. Due to its high trade openness, Botswana receives a high importation of food staffs from South Africa. South Africa has a large trade surplus with Botswana. Botswana's smallholder livestock farming sector and the country at large is facing a challenge in exploiting the growing national and regional demand for meat, as well as preferential access to the EU market.

The following chapter therefore reviews literature on livestock productivity and development. The chapter provides both the theoretical and empirical literature reviews of the subject matter.

CHAPTER 3

LITERATURE REVIEW

3.1 Introduction

The purpose of this chapter is to review theoretical and empirical literature on agricultural and livestock sector improvement role to economic development. This review of literature sheds some light agriculture's role from early development thinking and agricultural productivity in growth and development. The empirical literature review part gives insights on different tools used to analyse the livestock development role to economic growth. The chapter subsequently instructs the design of model. The chapter is structured as follows; 3.2 theoretical literatures which focus on the agricultural development and productivity; 3.3 theory of CGE modelling; 3.4 empirical literature on the livestock sector development and economic growth and; 3.5 chapter summary.

3.2 Theoretical Literature

Early literature has regarded agricultural growth and productivity as crucial in accomplishing the goals of sustainable growth and substantial poverty reduction in developing countries. According Mellor (1976), agricultural productivity growth is vitally important if agricultural output is to increase at a prompt rate to meet growing demand for food for the growing non-agricultural population, and as source of employment in developing countries.

3.2.1 Agriculture's Role from Early Development Thinking

The early development literature viewed agriculture in two extreme views; as simply a reservoir of unemployed or underemployed labor, with low incomes and living standards, from which these unproductive workers must eventually be moved by economic growth in the non-agricultural economy and; the alternative extreme view is that the agricultural sector itself must generate the growth that will eventually release labor and other resources.

Prominent scholars, Lewis (1954) and Ranis& Fei (1961) were for the first extreme view while Schultz (1953) and Jorgenson (1961) were for the second viewpoint.

Lewis (1954) viewed agriculture to have surplus unproductive labour which needs to be transferred to the productive activities (industrial sector) to jump start economic development. Lewis contended that this relocation of factors of production is due to the greater wage differential between the two sectors because of market imperfections nature. In addition, Ranis and Fei (1961) contended that the industrial wage will not increase as labour from agriculture to industry. Thus therefore, the wage paid by the industrial sector to attract agricultural labour depends in large part upon the terms of trade between the two sectors brought about the increase in productivity and the resulting increase in output in the agricultural sector (Yorgason 1972). The viewpoint was based on an economy which is sufficiently productive to produce enough food with labour to spare.

For the second extreme view, prior to Lewis, Schultz (1953) established that the low agricultural productivity is associated to the sector's technological feature, thus, agricultural improvement is a requirement to trigger economic development. Jorgenson (1961), conquered that, the growth of the non-agricultural sector is contingent on a positive and growing 'agricultural surplus' because if technological changes in agriculture are not rapid enough, agriculture can never produce either a food surplus or release its 'surplus labour' productively to the industry. Schultz (1964) further in support of Jorgenson conquered that any withdrawal of workers from agriculture will result in a reduction of agricultural output. This Schultz-Jorgenson is, therefore, the message that simultaneous growth of agriculture and industry is necessary both for the efficient transfer of 'surplus labour' as also for a 'sustained growth' of both the sectors in a mutually complementing manner. Schultz-Jorgensen's arguments are thus an important link in realising the potential of labour transfer made by

Lewis and advanced by Fei and Ranis. It is now required for 'balanced growth,' a strategy of development keeping 'both agriculture and industry under focus.'

Following the Green Revolution experience by Asian countries, to achieve 'shared' growth, the overall economic growth must yield a maximum pay-off in terms of poverty reduction- thus poor people be able to connect to that growth (i.e. the 'quality' of growth) (Christiaensen et al., 2006). This is in cognizant that majority of the poor people in the developing countries depend more on agriculture for their livelihood hence turn to participate and gain more from agricultural GDP growth than from an equal amount of GDP growth emanating from any other sector than agriculture.

3.2.2 Agricultural Productivity in Growth and Development

Productivity captures the economy's ability to 'harness its physical and human resources to generate output and income' at national level, (Productivity Commission, 2009). From several agricultural productivity definitions across literature- as general output per unit of input, farm yield by crop or total output per hectare, and output per worker, there is often confusion between increase in output and increase in productivity. There is therefore a need for a clear distinction between the two since these do not necessarily have similar impacts. The output and productivity increase, in some cases, increase together while in some other cases they may vary inversely with differential consequences for poverty. A new technology, for example can have a variety of impact with different consequences for output, profit and employment. If the technology reduces the quantity of inputs needed, production costs will fall raising profits, but output may not be affected and employment could be reduced. However, extent to which the factor demands offsets their displacement of the pure productivity effect will depend on the time of adjustment and the nature of demand for the output. Production cost reductions are passed through inter-industry transactions, further lowering prices and stimulating demand and increasing production in other sectors, (Hanson and Rose, 1997). If instead technology raises yields, output and probably employment will increase, but profits not necessarily increase. Increase in employment may raise households' incomes. As incomes increase, households save more and spend more, stimulating growth and investment in other sectors. These savings for investment in both rural and urban areas are derived from surplus agricultural income which works through forward linkages to urban areas. Alternatively, if the technology raises labour productivity, wage rates will increase but possibly at the expense of the labor quantity employed and profits with indeterminate output effects. A technology that permits the expansion of cultivated area might raise output, employment and profits but is likely to lower yield. The agricultural productivity improvements provides sufficient food for a growing non-agricultural population hence directly satisfying the basic human needs since it combines the natural resources, such as land and agro-ecological assets, with human effort for its production (Timmer, 1995). Agriculture therefore contributes to economic development through its provision of better caloric nutrient intake by the poor, food availability, food price stability, and poverty reduction.

To increase productivity, Urgessa (2015) suggests that agricultural productivity can be increased by using two ways; (i) through improvement in technology given some level of input and (ii) the other option is improving productivity to enhance the output per household labour ratio of rural household farmers, given fixed level of inputs and technology. However, with rapid global technical change and increasingly integrated markets, technology adoption has been uneven across resource-poor regions due to its costs and unsuitability. Agricultural productivity is considered the most important factor in determining the speed and extent of poverty reduction as it is both pro-poor and pro-growth.

In an economy-wide in general, the change in commodity price and factor income composition by industry affects the households' consumption patterns differently across brackets hence affecting the economy-wide consumption mix. This mix is also affected by the different overall marginal propensities to consume (and save) between income brackets. These consumption pattern changes then feed back to the production sectors, causing a change in the overall level and mix of the intermediate goods and then further rounds of factor adjustments, (Hanson and Rose, 1997). The ensuing demand effects will trigger yet another set of production, income, and consumption changes until a new equilibrium is found. In other words, successful agricultural innovation is a dynamic process that reflects natural endowments, the degree of demand and supply for agricultural inputs and outputs, and the incentive structure for farmers, scientists, and the public and private sectors. As both the Green Revolution and the "induced innovation model" revealed, agricultural productivity growth requires fostering the linkages between the agricultural and non-agricultural sectors,(Meijerink, G. & P. Roza. 2007).

3.3 Theoretical Literature on CGE Modelling Analysis

One of the basic ideas of economics is the general equilibrium theory of the competitive market economy which was pioneered by Walras (1877). Walras provided the general equilibrium system by describing the complex economic system with the interactions of independent economic agents. Edgeworth (1881) analysed Edgeworth box- the well-known tool of general equilibrium analysis of exchange. Arrow and Debreu (1954) provided proofs of existence and stability of equilibrium. Following the existence proof of Walrasian general equilibrium by Arrow-Debreu and availability of algorithmic methods devised to compute Arrow-Debreu equilibria, CGE model emerged.

CGE models, a family of economy-wide models, incorporates the fundamental general equilibrium links among production structure, incomes of various groups and the pattern of demand, (Dervis et al., 1982). Unlike the input-output (I-O) and social accounting matrix (SAM) multiplier models, the CGE models incorporate in the substitution possibilities and system constraints and are price endogenous. They are the price endogenous models because all prices must adjust until the decisions made in the productive sphere of the economy are consistent with the final demand decisions made by households and other autonomous decision makers, (Dervis et al., 1982). CGE models are based on actual data- social accounting matrix (SAM). From its name, the models are designed to establish a numerical framework for empirical analysis and evaluation of economic policies (Hosoe et al., 2010). CGE models are also referred to as Applied General Equilibrium (AGE) models or Social Accounting Matrix (SAM) based general equilibrium models.

They are the economy-wide models as they describe the motivations and behaviour of all economic agents/ actors in an economy and the linkages among them. These economic agents are first identified in the CGE model followed by specification of their behavioural rules. In the basic CGE model, the actors are producers and households. The government, rest of the world (ROW), capital and other accounts are included in fully developed CGE models. Independently, the agents make economic decisions that drive the economy together; producers seek to maximise profits subject to technological constraints whereas households maximise utility subject to budget constraints. The constraints express the economic intuition that resources are limited. The government behaviour is specified as an explicit sector due to lack of agreement on theories defining their behavioural responses to changes in relative prices. It therefore enters the model as a powerful actor. Through the price system, the government affects economic performance and/or structure through alteration of the incentive structure by changing taxes.

Based on the representative agents optimising behaviour, the agents respond to relative prices than absolute prices. Thus, the change in relative prices prompt optimisers the need to change their production, trade and consumption patterns. Inevitably, the supply and demand quantities are homogenous of degree zero in all prices-thus equi-proportionate changes in all prices leave the quantities demanded and supplied unaffected, (Tlhalefang, 2007). In CGE models, the economic system is assumed to be price (relative) sensitive hence price normalisation is of importance in the CGE models. The models, therefore, solve given relative prices- ergo one price or an index is selected as a numeraire, i.e., a price against which all prices are measured relative to.

The CGE models are found to embody the circular flow of income- thus income flows just like blood flow in the body, flows in a circular process in an economy. This is indicated by an underlying principle that for every agents' total income, it must equal its total expenditure in the CGE model. This is defined in the CGE model by, every payment from one agent to another affects the budget of the recipient, who must then spend the additional income according to some behavioural rule. This is achieved through the help of the system constraints in the economic system. The real system constraints require that quantity demanded must equal the quantity supplied in all markets; thus, commodity demands equals commodity supply and factor demands equal factor supply in the domestic markets. The nominal system constraints, which are the macroeconomic conditions, requires the balance of government, capital and rest of world accounts. By defining government and foreign savings residually, the ROW and government accounts are normally guaranteed to balance. The neo-classical closure rule which explains investment as determined by savings validates the investment-savings balance. Therefore, CGE models are equilibrium models.

These system constraints which ensure the matching of production and consumption plans in the CGE models, an equilibrium solution is realized from economic agents maximising their welfares and the same satisfying the system constraints. This overall equilibrium solution provides quantities, prices and value flows consistent with the environment and system constraint of the economy. Should a mismatch arise between supply and demand, prices adjust until quantities demanded and supplied equate and all macroeconomic conditions are satisfied. Through the price equilibrating mechanism, this conforms to the models' reliance on basic competitive equilibrium, thus, specifying prices as equilibrating variables means that markets are functioning perfectly whilst specifying quantities as the equilibrating variables implies that markets are working imperfectly or are non-existent.

The model closure is an inevitable problem in the CGE models hence a necessary condition to resolve it for existence of CGE models solutions. In resolving the problem, the neo-classical CGE models fix factor supplies, foreign savings, word prices and tax rates and by assuming that total investment is determined by savings. Fixing factor supplies reflects the argument that in the long-run there is full mobility and employment of factors. Lofgren *et* al., (2002) outlined that, theoretical CGE models are cast in long-run equilibrium mode and, hence, simulate the implications of economic and policy shocks on production and consumption patterns and on the allocation of resource.

3.4 Empirical literature

Various empirical literature support productivity improvement for poverty reduction (Mellor, 1999), employment creation (Schneider and Gugerty, 2011), increase food availability and access as well as rural incomes (IFPRI, 2011). However, an appropriate methodology for measuring productivity effects is a subject of debate. This section therefore provides methodological approaches employed in various literatures on the subject matter.

Ibrahim et al., (2017) investigated the role of livestock in the economic development in Mogadishu, Somalia. The study used descriptive statistics method using data on the Agricultural production of livestock and Farming, and the Economic Development from March-28 to June 2017. The results showed that poor livestock production leads to low economic development. The study recommended for agriculturalist skills improvement in order to increase the agricultural production.

Ali and Chaudhry, (2015) studied the impact of livestock output on poverty in Pakistan by using annual time series data for the period of 1972-2010. The unit root test, Jahansen's cointegration method and vector error correction techniques were used. The results showed that increased livestock output reduces poverty levels, to increase remittances, enhance credit to private sector, education and health expenditure. The study therefore recommended for the development of the livestock sector as is found to be helpful in promoting income sources and poverty alleviation.

In investigating the determinants of agricultural productivity and rural household income in Ethiopia , Urgessa (2015) used an Pooled ordinary least square (POLS), fixed effects (FE) and random effects (RE) model to examine the relationship between productivity and income. The study analysis was based on the Ethiopian socio-economic survey of 2011/12 and 2013/14 data. The results showed that labour productivity, non-farm income and land productivity are found to be the most determinants of household income. The study recommended for increase in land-labour ratio as important for agricultural productivity improvement and promotion of both farm labour and non-farm income in rural household income enhancement.

Kulshreshtha et al., (2012) used the regional multiplier analysis to examine the economic impacts of livestock production in Canada. The regional multiplier analysis considered an input-output model. The study estimated the total economic impacts of cattle production (those associated with the sector directly and including all the regional level repercussions). Cattle production was found to have strong linkages with economic activities, including slaughtering and meat production industries. The live cattle production farms were found to be beneficial to the economy not only through direct impacts on the national / regional economy, but also generated additional impacts through secondary mechanisms – indirect and induced. The study concluded that if relative contributions of livestock sector are estimated using direct impacts only, it will lead to serious underestimation hence cattle sector is found to make much higher contribution to the economy than what is obvious from traditional measures related to direct contribution.

Tlhalefang and Mangadi (2012) used a static CGE model to analyse the agriculture sector's performance and evaluate its development impact on the Botswana economy. The study examined a 5 percent increase in Hicks-neutral technological progress in the agricultural sector. The CGE model was calibrated to the SAM database for the Botswana economy in 2004/05 which was produced for the Global Trade Analysis Project. The elasticity of substitution values were exogenously determined. The results showed that raising the agriculture sector productivity leads to the improvement in overall economic well-being that is proportionally distributed across rural and urban households. The study recommended that agriculture productivity improvement policy needs to include a component that will allow for an increase in farm-workers' income to prevent for income inequality arising from the increase in agricultural output.

Cabral, (2016) built a dynamic recursive general equilibrium model to assess the effects of artificial insemination program implemented in Senegal's cow sector from 2008 to 2011 aimed at boosting cow production to increase the sector's supply of raw milk, processed milk, processed meat, and leather. The model was built under the assumption of a small open economy. As artificial insemination relies mainly on budgetary efforts, the model is therefore built with the total factor productivity (TFP) endogenized and expressed as a function of i) R&D and externalities for the cross-bred cows and ii) only externalities for traditional cows. The effects of the artificial insemination program are then simulated on sectors and factors remuneration, and hence GDP and welfare. The model was built based on a 2005 social accounting matrix (SAM) of the Senegalese economy that focuses on livestock. The results show that production of cross-bred and local cows significantly increases under the program, as does production of processed meat, raw milk, processed milk, and leather. However, the increase in TFP seems to have a depressive effect on returns to factors, as less intensive factors used by cow sector are needed to produce the same output decreasing households' income. However, consumption prices also decrease for all households, and the price effects seem to overcome the income effects.

In integrating livestock in the CAADP framework Gelan *et al*., (2012), Gelan *et al*., (2013) and Engida *et al*., (2015) extended an existing dynamic recursive general equilibrium model for the African countries-Tanzania, Kenya and Ethiopia respectively to better model the livestock sector. This extended dynamic CGE model for these three respective countries was built with a separate herd dynamics module translated into algebraic equations in a computer programme in the GAMS which enabled the specification of stock–flow relationship, distinguishing between the capital role of livestock and the flow of livestock products (dynamics of the stocks). The model developed is the recursive dynamic version of the standard computable general equilibrium (CGE) model originally developed by IFPRI. The model was calibrated with the trade elasticities borrowed from the GTAP database. Livestock categories had low constant elasticities of transformation meaning a large relative price fall will be necessitated to stimulate an increase in exports. On the demand side, the authors specified a linear demand system calibrated with income elasticities estimated for respective countries as econometrically estimated by other authors for those respective countries. For macro closure rules, the model, for all respective countries, was simulated under full employment of factors mobile across sectors, allowing the nominal wage rate to adjust to balance supply and demand; investment driven by available savings determined by a fixed marginal propensity to save out of households' income; floating nominal exchange rate ensured balance in the external account and finally tax rate was fixed and government savings was flexible. From the Total Factor Productivity (TFP) shocks to three agricultural subsectors—cereals, cash crops, and livestock, the livestock sector, in all the three countries, was found to increase various measures of GDP and important in combating food insecurity. Livestock sector productivity growth was found to lead to greater factor income growth-particularly labor income since labor is the predominant asset of poor households and hence large income gains and food consumption growth are realized under the livestock-led scenario, (Gelan *et al*., 2012; Gelan *et al*., 2013; Engida *et al*., (2015).

3.5 Overview of the Literature

The chapter presented the theoretical literature on agriculture and development based on agriculture's role from early development thinking; and agricultural productivity growth and development; theoretical literature on CGE modelling analysis; and empirical literature on different methodology on productivity improvement impact on poverty reduction, employment creation, increase food availability and access as well as rural incomes. With above several scholars' theoretical arguments, the main basis for agricultural transformation lies between these prominent theorists' arguments; Lewis Ranis-Fei and Schultz-Jorgenson. For Lewis Ranis-Fei, the transfer of labour happens because the sector has reached a saturation point, thus surplus labour, therefore can longer contribute much to the economic development. For Schultz-Jorgenson, they assert that the agricultural sector has not yet raised its production to a level where there can no longer be any technological advancement that could cause an increase in agricultural output, or have an effect to the economy. We can therefore argue that Lewis case does not apply to Botswana case since excess labour exists not because farmers are producing. With existence of unutilized resources, our study therefore is anchored around Schultz model.

Empirical results shows a common partial equilibrium analysis to overstate both sectoral and economy-wide impacts of productivity growth in agriculture because it ignores price transmissions and factor market linkages, hence CGE models are found to capture these links and show how the benefits of agricultural productivity growth are dampened throughout the economy, (Wobst, 2000).

The next chapter therefore presents a detailed methodology adopted by this research to achieve its objectives.

CHAPTER 4

METHODOLOGY

4.1 Introduction

This chapter presents the important aspects of the CGE methodology and the datasets used to achieve the study objectives. The study adopted Thurlow (2004) South African recursive dynamic CGE model which is an extension of the static standard CGE model developed by Lofgren *et al*., (2002) under the auspices of the International Food Policy Research Institute (IFPRI). The model structure is used with minor changes to help achieve the research objectives. This is to render the model to capture the Botswana economy structural features. The chapter therefore begins by first providing a detailed description of the adopted Lofgren et al., (2002) static standard CGE model. It proceeds by giving; 4.2 an overview of the model, 4.3 description of the model, 4.4 data sets, and finally 4.5 summary of the chapter.

4.2 The Static Standard CGE Model

The Lofgren *et al* (2002) static module specification component describes the model application of a single country, multi-sector, multi-factor static general equilibrium model. It includes several features designed to reflect the characteristics of developing countries. It follows the neoclassical-structuralist modelling tradition presented in Dervis et al., (1982) which incorporates more advanced functional forms and policy instruments aimed at capturing features of developing economies to increase the scope of policy analysis. The model is built in the spirit of Walras which states that all markets are in perfect competition and only relative prices matter with all markets clearing. The model distinct features include; taking into account household (home) consumption of non-marketed (in particular agricultural) commodities but implicitly assuming that the underlying farm household model is separable (recursive), explicit treatment of transaction costs for commodities that enter the market sphere, and a separation between production activities and commodities that permits any activity to produce multiple commodities and any commodity to be produced by multiple activities.

The decision to adopt the Lofgren *et al* static version of the model as a starting point for our dynamic module for this study was influenced by the following key features, that, it allows for:

- “numerous factor market features to be captured flexibly;
- a generalised treatment of trade relationships is permitted by integrating provisions for (i) non-trade commodities, i.e., commodities that are neither imported nor exported, (ii) competitive imports, i.e., commodities that are imported and domestically produced, (iii) complimentary imports, which are commodities whose supply is met entirely through imports, (iv) commodities that are exported and consumed domestically, (v) commodities that are exported but not sold domestically and, (vi) domestically produced commodities that are only sold in the domestic markets;
- the use of the small- country assumption in conjunction with the Armington insights and, thereby enabling cross-hauling, i.e., a country importing and exporting the same good, which is a feature of trade statistics, to be accommodated, accords the domestic price system some degree of autonomy and does not result in extreme specialization in response to price fluctuations;
- putty-clay structure for new capital allocation scheme; and,
- Mining production to be predominantly driven by a combination of changes in world demand and prices, and other exogenous factors that might include the gradual depletion of mineral resources” (Tlhalefang, 2019).

4.3 Data Sets

Three datasets are needed to calibrate the model. One is the social accounting matrix (SAM), the elasticities and information on exogenous variables and parameters of the dynamic module.

4.3.1 The SAM as a Data Framework

Since the Thurlow recursive dynamic CGE is built conferring to the SAM approach to modelling, the same SAM is the primary data framework deployed for its statistical underpinnings and theoretical formulations. The matrix framework helps in the development and understanding of the model structures/ construction and results analysis.

The SAMs are a representation of the economy at one point in time (base year). They are specifically an accounting framework that assigns numbers to the incomes and expenditures in the circular flow diagram, (Breisinger *et al.*, 2010). The SAMs therefore emerge and correspond to the circular flow diagrams, as shown in figure 4.3 in the Appendix B1. Within the economy, the productive activities purchase their inputs (land, labour, and capital), owned by households (and enterprises) from the factor markets and the intermediate from the commodity markets which are then used to produce goods and services. Since the economy alone cannot meet its full demand, they are supplemented by imports which are then sold through the commodity markets to households, government, investors and foreigners. For every purchase (expenditures) between institutions, they become another institutions income, thus the circular flow of income within the economy.

The SAM, as a comprehensive square matrix, contains an economy wide data framework depicting the circular flow of income in the economy of a nation. It captures all transfers and real transactions between actors and institutions (as discussed in the next sub-section). In the matrix, each account is represented by a row (indicating incomes to the accounts) and corresponding column (indicating expenditures from the accounts). Each account’s total revenue (that is row total) in the SAM must equal the account's total expenditures (column total) following an underlying principle of double-entry accounting requirement. It is thence that the quality of the results derived from the CGE model depends on the data used-thus the SAM used as data frameworks supporting a wide range of applied equilibrium models, including CGE models. A general example outlay of the basic structure of a macro SAM can be depicted as in the table 4.7 in Appendix B2. The macro SAM indicates the linkages and relationships within the economy as portrayed in a more compact presentation in which activities, commodities, and households (among other accounts) are aggregated into single accounts, (Al-Riffai et al., 2016).

For the full description of the macro SAM, see Appendix B3.

4.3.2 Other Data Inputs

Apart from the SAM database, two additional data sets are required to 'calibrate' or initialise the model. These include; the behavioural parameter values of the model (which includes production, consumption and trade elasticities) and the dynamic sub-model information on exogenous variables and parameters (which includes; the observed and projected growth sectoral value added rates, and of government consumption; projected population growth; factor accumulations (labour by each skill type, etc.); and depreciation rate).

4.3.2.1 Behavioural Parameter Values Estimation (Elasticities)

This set of databases imposed in the model is needed for the consumption, production, and trade functions. Cognizant that the SAM database cannot determine all the parameter values of the consumption, production, and trade functions, these additional data in the CGE modelling are therefore taken from other CGE models for Botswana and/ or other data sources- econometrically estimated.

4.3.2.2 Projection on exogenous variables and parameters of the dynamic sub-model

This included; (i) the observed and projected growth rates of sectoral value added, and (ii) of government consumption; (iii) projected population growth, (iii) factor accumulations (labour by each skill type, etc.); and depreciation rate.

4.4 Transactions Relationships

The adopted model is derived from the real-world SAM database hence describing the economy actual transactions. Apart from identifying and defining the model transactional relationships and introducing model notations being helpful, this also increases the behavioural relationships substance particularly to those governing inter-institutional relationships. Furthermore, a fortiori, to use a SAM as a framework for theory requires that the cells of such a matrix be filled instead with algebraic expressions, which describe in conceptual terms how the corresponding transaction values might be determined, (Pyatt, 1988).

The transaction relationships, split in two parts, are summarised in table 4.2 in Appendix A2. The domestically consumed (composite) commodities (*QQ*) volumes are distributed between intermediate demand ($QINTDEM_{c,a}$) and final demand composed of households ($QCDEM_{c,h}$), enterprises ($QENTDEM_c$), government ($QGOVTDEM_c$), investment ($QINVESTDEM_c$), stock changes (*qdstokconstc*) and exports ($QEXP_c$). The prices of the domestic composite commodities (PQD_c) are the same irrespective of the agent purchasing the good, reflecting the one price assumption, thus prices are common across the rows. This then gives the values of total domestic demands at purchaser prices be defined by PQD_c*QQ_c. For those commodities demanded abroad, their domestic price (PE_c), differs from the domestically demanded commodities. This reflects the notion that the commodities sold at different prices should be treated as different commodities. PE_c is therefore defined by the product of world exports prices ($PWEXP_c$) and the sum of exchange rate (*EXR*) and the export duties (*tec*)-acting as a price wedge between domestic and exported commodities entered into the commodity columns; ($PE_c = PWEXP_c$*(1- tec)*EXR). The domestic prices of exported commodities are seen to be misleading as they do not accord with the law of one price despite the export demand recorded in the commodity row in the SAM. However, the latter representation is found to be advantageous as is a space saving device that removes the need to include separate rows and columns for domestic and exported commodities.

The total domestic commodity production (QXC_c) come from the domestic producers who receive the common composite commodity supply prices (PXC_c) regardless of which activity produces the commodity. The total domestic commodity output value is the defined by PXC_c*QXC_c. The import commodities supply ($QIMP_c$) are valued carriage, insurance and freight (cif) paid. The domestic price of imports ($PIMP_c$) are given by the product of world prices of imports ($PWIMP_c$) and the sum of exchange rate and an *ad valorem* adjustment for import duties (tmc). All domestically consumed commodities are subjected to sales taxes (tsc). The basic prices (PQS_c) are then uplifted by one times tsc to obtain the consumer prices (PQD_c). Total commodity supplied (PQD_c*QQ_c) is then equated to the total commodity demanded domestically in equilibrium.

Since activities produce multiple outputs, their output quantities (QX_a), they are formed from the multiple commodities produced by an activity. These domestic production activities receive average activity prices (PX_a) determined by the commodity composition of their outputs and exhausts their revenues (PX_a*QX_a) on payments to intermediate inputs and primary inputs (Q$FACT_{f,a}$). Each of the activities pays the average factor prices defined by economy-wide wages ($WFACT_f$) times the activity-wage distortion terms ($WFACTDIST_{f,a}$). This is to accommodate for the wage differences possibility across activities anchoring from external factors like status, comfort, health risk, *etc*., or account of market segmentation. To increase the model flexibility, factor price may be allowed to vary according to the activity that employs only on account of differences in the activity-specific wage distortion terms even though activities are paying the same economy-wide price for each factor. Further, each activity pays production taxes at rates (*txa*) which are proportionate to the value of activity outputs. Consistent with the zero economic profits assumption, activities incomes are all used to pay for the inputs including indirect taxes.

Both the domestic and foreign owned factors production is allowed for domestic use in the model so the factor income for these factors is accrued from the domestic and foreign activities. The total income for each factor is given by the sum of factor payments by domestic activities ($WFACT_{f,a}*QFACT_{f,a}$) and the predetermined factor payments by foreign activities (*rowfact*), denominated in foreign currencies. After allowing for depreciation (*dep*), thus payments required for maintaining the integrity of the capital stock, and the payment of factor taxes (*facttax*), the residual factor incomes (*YFACTDIST*) is paid to factor owners (households, enterprises and government) and the rest of the world in fixed proportions.

Correspondingly, domestic institutions receive income from different sources. Households receive incomes from inter-households transfers ($hxhconst_{h,hh}$), transfers from enterprises ($hxentconst_h$), government ($hxgovtconst_h$) and the remittances from the ROW ($hxrow_h$), with remittances denominated in foreign currency. Total household income (YHO_h) is used to pay direct taxes at average rate ($dirty_h$), and households' savings, thus after-tax income times the fixed average savings rate, are paid. The savings rates ($SAVHH_h$) are fixed exogenously in the base configuration of the model. The average savings rates are given by the relative savings rate ($capsavhxh_h$) multiplied by the household savings rate adjuster (*SAVADJ*) allowing savings rate to vary with the relative savings rate remaining constant. The residual household income is then allocated between inter-household transfers and consumption spending, with the pattern of consumption expenditures determined by the household utility (either C-D or Stone-Geary) functions.

In the same manner, the enterprise account receives income from factor sales, primarily as retained profits, transfers from the government (*entxgovtconst*) and rest of the world (*entxrow*) denominated in foreign currency. The enterprise expenditures include, direct tax payments at a rate (*dirtye*) and consumption (assumed to be fixed in real terms) defined by product of quantity of enterprises consumption ($QENTDEM_c$) and the consumer prices of commodities and summed across commodities, and savings (*CAPSAVENT*)- defined as a residual, thus the difference between enterprises income (*YENT*) and committed enterprises expenditure (*ENTEX*) ensuring that enterprises income is all exhausted.

Analogous to households and enterprises, government also receives its income (*YGOVT*) from different sources; from the various tax instruments: indirect taxes (*INDIRTAX*), direct taxes (*DIRTAX*), exports duties (*EXPTAX*), import duties (*IMPTAX*) and factor taxes (*FACTTAX*), all of which are dependent production, trade and consumption values variations. The other government income source is factor sales defined by fixed government shares in factor ownership (*govtvashare*) multiplied by the factor income for distribution. Lastly, government income is accrued from transfers from the ROW (*govtxrow*) in the form of aids and grants. At equilibrium, government expenditure (*EXGOVT*) is equated to the sum of consumption expenditure given by the sum of the product of the volumes of government ($QGOVTDEM_c$) times the prices of commodities and summed across commodities, and government transfers to other institutions. Government savings (*CAPSAVGOVT*) is defined by the difference between government income and expenditure.

Total savings (*TOTSAVE*) paid as income to the capital account is composed of savings from all the domestic institutions and savings from the rest of the world (*CAPSAVROW*). The domestic investment demand comprises of fixed capital formations (*QINVESTDEMc*) and the stock changes (*qdstokconst*). The summation of the quantity of fixed capital formations multiplied by the prices of commodities summed across commodities plus the value of the stock changes equals to the total value of investment (*INVEST*). In equilibrium, total investment expenditure is equated to savings.

The rest of the world account incomes (expenditures by the domestic economy to the RoW) are made up of the imported commodities values and factor services. On the other hand expenditures by the rest of the world account (incomes to the domestic economy from the RoW) comprises of the values of exported commodities and net transfers to domestic institutional accounts. All these transactions are transformed into domestic currency by multiplication with the exchange rate.

4.5 The Quantity System

The figure 4.2 in Appendix A3 shows the quantity flows of marketed commodities in the model. The commodity output from activity 1(QX_{a1}) is combined with that from other different activities (QX_{an}) by the CES function to produce aggregate domestic output (*QX*) of each commodity in the economy. This aggregate domestic output then allocated between the local market for sale (*QDEM*) and the rest of the world for aggregate export market (*QEXP*), a decision governed by the CET function. However, in specific cases where the commodity is not exported, it is all supplied for sale to the domestic market. Since the economy cannot meet its full demands, the domestic sales output is supplemented with aggregate imports through the CES function to give the composite commodity (*QQ*) which is then sold through the commodity markets to the domestic final demand comprised of household consumption (*QCDEM*), government consumption (*QGOVTDEM*), investment (*QINVESTDEM+qdstokconst*), and the demand generated by domestic producers for intermediate inputs (*QINTDEM*).

4.6 Price System

CGE models are best known for their distinctive feature of handling prices. To explain the price system associated with the above flow of marketed commodities, the below figure depicts a detailed overview of the price relations depicting how the composite commodity prices are determined in the model. The price system entirely follows McDonald, (2001) price relationship structure description as shown in figure 4.2 in Appendix A4.

The composite commodities consumer supply price (PQS_c) is given by the weighted price averages of commodities produced and consumed locally ($PDEM_c$) and imported commodities domestic prices ($PIMP_c$). The imported commodity prices are described by the world prices (PWM_c) multiplied by the exchange rate (*EXR*) adjusted by *ad valorem* import duties (*tmc*). The supply prices, adjusted by *ad valorem* sales taxes (*tsc*), excludes sales so to ruminate the composite consumer price (PQD_c). Similarly, the commodity producer prices (PXC_c) are defined by the weighted averages (updated in the model through first order conditions for optima) of the received domestically produced commodities prices sold in the domestic and international (PE_c) markets. The export market prices are described by the world market price of exports (PWE_c) times the exchange rate (*EXR*) minus any export duties due (defined by *ad valorem* export duties (*tec*).

Each activity receives an average price per unit of output (PX_a) defined by the constant weighted average domestic producer prices. This takes into consideration the indirect/production/output taxes (*txa*) which after being paid, it is divided between aggregate value added payments (the amount available to pay primary inputs) ($PVAD_a$) and aggregate intermediate inputs ($PINT_a$). Intermediate inputs per unit of aggregate intermediate input total payments are described as the weighted sums of the inputs prices (PQD_c).

4.7 Production System

From the CGE empirical application, production requires a specific functional form defining its relationship. In that case, a number of functional forms by economists have been developed which takes into consideration the imposition of minimum priori restrictions on substitution elasticities. These functional forms include Leontief imposing a restriction on inputs to be compliments, Cobb-Douglas (C-D) restricting all pairs of inputs to have unitary substitution elasticities, and constant elasticity of substitution (CES) function which requires that substitution elasticities be constant across inputs, its substitution elasticity is an empirically determined parameter and accommodates both the C-D and Leontief cases, (Tlhalefang, 2007). Despite the latter, Tlhalefang further noted that, these functional forms render the model inflexible as they cannot accommodate complimentarity between two inputs as well as substitutability between different pairs of inputs. This however is overcome by adducing Leontief (1947) theory of nested production structure where an overall production structure is decomposed into several sub-production structures, with each of sub-production structure having fewer inputs, on the basis of appropriate technical information (Tlhalefang added). Figure 4.2 in Appendix A5 shows the pictoral representation of the latter explanation.

It is for the latter reason that the CGE model used in this study makes use of a two-nested production structure that incorporates both intermediate inputs and primary inputs. At each of these two production stages, a specific functional is used to describe each sub-production structure. From figure 4.2 above, production activity is assumed to be using two intermediate (*QINTDEM*) inputs and two primary factors (*QFACT*) for simplicity. In the arc are the substitution elasticities characters with the subscripts indicating the level of nest for which the respective substitution elasticity relates to. At the top-level of the production structure, technology is specified by a constant elasticity of substitution (CES) function or a Leontief function of the aggregate primary inputs or value added quantities (*QVAD*) and aggregate intermediate input quantities (*QINTA*) to produce the final output (*QX*). At the base level of the production structure, value added is a CES function of primary inputs $QFACT_1$ and $QFACT_2$ whereas the aggregated intermediate input (*QINTA*) is given by the Leontief function of the individual intermediate inputs ($QINTDEM_{c1}$ *and* $QINTDEM_{c2}$).

4.8 The Standard Model Behavioural Relationships

Following the SAM disaggregation of factors, activities, commodities, and institutions, the SAM accounts present the agents that can be included in the model with the record of all their associated transactions. The model is written as a set of both linear and non-linear simultaneous equations, with no objective function, defining different economic actors' behaviour. This agents' mix of linear and non-linear behavioural relationships govern the economic environment (described by market equilibrium conditions-both for factors and commodities; macroeconomic balances- balances for Savings-Investment, the government, and the current account of the rest of the world; and dynamic updating equations) in which these agents operate. Thus, the equations include a set of constraints that needs to be satisfied by the system. Table 4.1 (in appendix A1) gives a summary of the model relationships by reference to the sub matrices of the SAM and Table 4.2a and 4.2b (in appendix A2), gives the record of all agents associated transaction relationships.

4.8.1 Domestic Production

Domestic producers (represented by activities) are assumed to operate in a perfectly competitive market and use multiple inputs to maximize their profit subject to technological constraints. The profit is defined by the difference between the earned revenue (defined by activity yield level and commodity prices at producer level) and the cost of factors and intermediate inputs. Each activity is assumed to produce one or more commodities according to fixed yield coefficients and a commodity may be produced by more than one activity- an arguably realistic representation of agricultural activities. The production process of the model has a two-stage nested production structure which allows for the choice between a constant elasticity of substitution (CES) or a Leontief function. At the top level, technology specified by a CES or a Leontief function of quantities of value added and intermediate inputs. At the base level, primary factors of production (land, labour and capital) are assumed to be used for production of a composite factor (or value added) by CES function which allows for substitution between the inputs while on the other hand the aggregate intermediate inputs is a Leontief-type production function, which does not allow for input substitution, of disaggregated intermediate inputs. The set of factors used by activities are used up to the point where the marginal revenue product of each factor is equal to its wage (also referred to as factor price or rent-and may differ across activities not only for market segmentation but also for factor mobility). Factors demanded by producers and outputs demanded by households are assumed to be available in fixed supply at market clearing prices.

4.8.2 Institutions (Households, Enterprises, Government, Rest of World)

Households are assumed to maximize utility derived from the consumption bundle of the composite goods aggregated (from domestically produced and imported commodities) using the Stone-Geary utility function-allowing for subsistence consumption expenditure. This is arguably a realistic assumption applicable for our case as there is likely chance of substantial numbers of poor consumers/ households to exist especially in the agricultural sector. Household consumption comprises of home and marketed commodities. The commodities are valued at producer prices while the marketed commodities are valued at market prices inclusive of commodity taxes and transaction costs. The households' different commodity consumption demand is distributed across both the market and home commodities according to linear expenditure system (LES) demand functions which is derived from maximization of a Stone-Geary utility function. As disaggregated in the SAM, households receive their income from factors of production (directly or indirectly via enterprises), transfers from other institutions (enterprises, government, and the rest of the world). They spend their income on consumption, pay direct taxes, savings, and make transfers to other institutions. All transfers between the rest of the world and domestic institutions and factors of production are fixed in foreign currency. After paying taxes, savings, and transfers to other institutions, the remaining income is spent on consumption.

The enterprises receive some of its income from factor incomes which may not be paid directly to households and/ or from transfers from other institutions. Since enterprises do not consume like households, their incomes are allocated to direct taxes, savings, and transfers to other institutions. With this regard, payments to and from enterprises are modelled in the same manner as the payments to and from households.

For government, it collects taxes and receives transfers from other institutions just like households and enterprises. All these taxes are fixed at *ad valorem* rates. The government income is then used to purchase commodities for its consumption (fixed in real quantity terms) and for transfers to domestic institutions-households and enterprises (which are CPI indexed). Government savings which is defined as the difference between government income and government spending is treated as a flexible residual.

Finally, the rest of the world institution has its transfer payments between itself and domestic institutions and factors all fixed in foreign currency. Foreign savings (current account deficit) is defined as the difference between foreign currency spending and foreign currency receipts.

4.8.3 Trade

The model assumes that all commodities (both imported and domestically produced) enter the market except the home consumed output. The domestic output can either be used for home consumption or sold to the market (local and external). For the marketed output, the Armington (1969) insight and small-country (i.e., price taker, on all agricultural export markets) assumptions are used to model their trade. The Armington approach presupposes that exports, imports and domestic commodities are all distinct and are therefore imperfect substitutes due to differences in timing, quality, and distance between the locations of activities. Thus, because of the reality relevance of substitution existing between imports and domestically produced goods, and between the exports and domestic goods as compared to between exports and imports.

In the first chain stage, the marketed domestic output is generated from aggregating domestic output from different activity outputs of a given commodity. This marketed output is aggregated by the CES aggregation specification under the assumption of imperfect substitutability between domestic, imported and exported commodities. The demand for the output of each activity is derived from the problem of minimizing the cost of supplying a given quantity of aggregated output subject to this CES function, (Lofgren *et al*, 2002. In the next stage in the chain, the aggregated domestic output is then supplied between the domestic demand and the export demand (rest of the world-ROW) under the assumption that suppliers maximize sales revenue for any given aggregate output level, subject to imperfect transformability between exports and domestic sales, expressed by a constant elasticity of transformation (CET) function.

In the international market, the small country assumption provides that, exports demands for the country are assumed to be infinitely elastic at given world prices. This export price received by domestic suppliers for exports (expressed in home country currency) is given by the world prices plus the export taxes (if any) and transaction costs incurred for moving the export commodity from the producer to the border. To the domestic market sales, the supply price is expressed as the price paid by domestic demanders (household, government, investment, intermediate inputs, and trade and transportation transaction inputs) minus the transaction costs of domestic marketing (from the supplier to the demander) per unit of domestic sales. For any commodity that is not exported, its total output is all supplied to the domestic market.

For an imported commodity, the demanded commodity by the domestic demanders is a composite commodity composed of imports and domestic output. This demand is derived on the basic assumption that the domestic demanders minimize costs subject to imperfect substitutability between imports and domestic output captured by a CES aggregation function.

Total market demand is therefore met through these import commodities which lack domestic production and domestic output for non-imported commodities. Analogously, the import demands are assumed to be infinitely elastic at constant world prices. The import prices paid by domestic demander for imports is expressed as the world prices inclusive of import tariffs (at fixed ad valorem rates) plus the transaction cost of moving the commodity from the border to the demander. In the same manner, the derived demand for the domestically marketed domestic output is met by domestic, hence their demands and supplies are equilibrated by the flexible prices.

The behavioural assumptions of the imperfect transformability between exports and domestic output sales and the imperfect substitutability between imports and domestically sold domestic output allows the model to reflect better the empirical realities of most countries. These latter assumptions give the domestic price system some degree of independence from the world prices and also helps prevent the unrealistic responses of exports and imports to economic shocks. Furthermore, the assumptions allow for a continuum of tradability and a two-way trade at the commodity disaggregated level to even very fine levels of disaggregation.

For this model, the assumption is that the country is a price taker for all imported commodities.

4.9 System Constraints

In achieving the macroeconomic consistency in the model, constraints on the behavioural relationships is observed. These constraints assure that agents operate within their budgets-thus captures the intuition that economic resources are limited relative to human wants. They describe the way macroeconomic variables adjust to general equilibrium in the modelled economy. To reach equilibrium in all the commodity and factor markets and that all macroeconomic conditions are satisfied simultaneously, mechanisms that guarantee that simultaneous equilibrium are contained in a CGE model. The simultaneous equilibrium ensures that, composite quantity supplied should equal quantity demanded in the commodity market; and total factor quantity demanded equals the total factor quantity supplied in factor market.

Further, the three macroeconomic conditions to be satisfied are; current government balance, external balance (the current account of the balance of payments, which includes the trade balance) and, savings and investment balance) must hold at equilibrium. The government current revenue equals the sum of government current expenditures (excluding government investment) and savings. In external balance treatment, the country's spending should equal its earnings of foreign exchange. Finally, for savings and investment, the country's total savings should equal it total investment. These latter three macro-economic balances are important as they provide a variety of choice to a relatively large number of pre-programmed alternative model closure rules in the GAMS code. It is worth noting that the choices do not influence the base simulation solution but the other simulations results.

4.10 The Dynamic Sub-Model

The preceding section described the Lofgren static model. To account for the second period effect in the model, the static model is extended to the recursive dynamic model. The recursive dynamic type of model assumes that agents' behaviour is based on the adaptive expectations rather than on the forward-looking expectations that underlie alternative inter-temporal optimization models, (Thurlow, 2004). This implies that economic agents make their decisions based on past experiences and current conditions, with no role for forward-looking expectations about the future (Lofgren, et al, 2002).

In updating the static module to dynamic module, a number of selected parameters are updated based on the modelling of inter-temporal behaviour and results from previous periods. This provides the necessary inter-temporal linkages (thus policy changes impact the inter-temporal effects on population and labour force growth, capital accumulation, factor productivity changes) and shifts in the sectoral demand and supply functions. This is done by embedding equations that updates the exogenous variables and parameters that drive growth in the within period sub-model with the main focus on structural disequilibrium in the labour market and the determination of sectoral allocation of investment. Together these effects form a projected or counterfactual growth path for the economy. Through consideration of the updated exogenous variables and parameters and mechanisms by which they are updated, policy changes are then defined in terms of changes in relevant exogenous parameters and the model is re-solved for a new series of equilibriums. This new series of equilibriums showing how economic indicators such as GDP, employment, *etc*., react to policy and non-policy shocks. The variation between the policy- effect growth and the counterfactual are interpreted as the economy-wide impact of the simulated policy. Below is an explanation a number of selected exogenous behavioral trends that are imposed on static model to transit to the recursive dynamic model.

4.10.1 Capital Accumulation

The total supply of capital stock is the first variable in which dynamics are modelled. However, the introduction of dynamics in the capital stock equation is a process that is charged with two problems; (i) the new capital (investment) goods, which are to be added to the capital stock, are expressed in units that are different from that of the capita stock-thus since in the SAM database, with investment goods being valued at purchasers' prices while a unit of physical capital at the marginal physical product of capital, there is need for the two variables to be expressed in same units for addition to proceed; (ii) the new aggregate capital is to be determined and describe how it is to be allocated across sector of destination.

These dynamics in the specification of the total investment, in almost all the CGE model applications, are not determined from an inter-temporal optimization problem. They are however derived parsimoniously through the specification of investment-savings balance closure rule and then total investment is distributed over the sectors of destination by use of value-capital approach (Thurlow, 2004). Abreast this approach, the new capital is allocated across sectors in proportions to their shares in the total profits or capital stock. As the total capital accumulation is equal to total saving, which is endogenous, according to the closure rule for investment-saving balance, this implies that the changes in the total capital stock are also endogenous thence at the beginning of the next period, the total capital available is determined endogenously by the previous period's capital stock and investment, (Tlhalefang, 2019).

Further, with the new capital allocation across sectors being influenced by each sector's initial share of aggregate capital income, the final sectoral allocation of capital in the current period is dependent on the capital depreciation rate and on sectoral profit-rate differentials from the previous period. The firms therefore are supposed to replace this obsolete capital with new capital in order to maintain output. The above-average capital returns sectors receive a larger share of investible funds than their share in capital income and the opposite is true for the below-average capital returns sectors. The firms therefore are supposed to replace this obsolete capital with new capital in order to maintain output. The above-average capital returns sectors receive a larger share of investible funds than their share in capital income and the opposite is true for the below-average capital returns sectors. The new capital stock comes about through investment of unspent consumption income. The cost of installing this new capital (which can be installing new equipment or training workers to operate new machinery) over and above the price of capital is accounted for in the model.

4.10.2 Population Growth

Population growth is assumed to generate high consumption demand level by directly affecting the income-independent component of consumption, that is, the committed quantities. Consequently, this raises the supernumerary income of household consumption. The income-independent component of consumption is assumed to grow at the same rate as of the exogenously given population growth of 1.3% per annum. Population growth rates are calculated separately then imposed into the model. The marginal rate of consumption is however is assumed to be unchanging for commodities, thus new consumers have same preferences as the already existing ones.

4.10.3 Labour Force Growth

Total labour supply is assumed to increase exogenously at the same rate as population growth. This latter update demonstrates the demographic and technological adjustments that are built on observed or differently calculated projected trends.

The model separates labour into highly skilled, unskilled and semi-skilled, and skilled supply. Across the periods in response to continuing changes in real wages, the highly skilled labour supply is assumed to adjust endogenously. However, there may be some exogenous adjustments to the highly skilled labour category between periods as is typical in most recursive dynamic models. Treating the highly skilled labour category in the model labour supply dynamics assumes that neither supply-constraint is binding, nor unemployment is involuntary. Labour supply is therefore seen as being driven by changes in real wages indicating the presence of an effective reservation wage.

Analogously, within a particular time period, the unskilled and semi-skilled, and skilled labour supply are assumed to be infinitely elastic at a fixed real wage. Real wage therefore adjusts between the periods rather than labour supply. The dynamic model assumes that unskilled and skilled workers real wage changes relative to highly skilled workers real wage changes in the past period. This specification allows for determining the lower skilled workers wages endogenously as well as exogenously determining the skilled-unskilled wage rates convergence.

4.10.4 Total and Factor-Specific Productivity Growth

Along with changes in factor supply, the dynamic model also takes into consideration changes factor productivity. Factor-specific productivity growth is imposed exogenously on the model based on observed trends for labour and capital. The real government consumption growth and transfer spending are determined exogenously between the periods, since within-period government spending is fixed in real terms. Moreover, the current account balance projected changes are accounted for exogenously.

Lastly, mining production is assumed to be driven predominantly by a combination world demand and prices changes, and other external factors (like the gradual exhaustion of non-renewable natural resources) to the model. Consequently, these sectors value-added growth and world export prices are exogenously updated between periods based on historical long term trends.

4.10.5 Government Consumption and Transfer Spending

Since government consumption spending and transfers to households are fixed in real terms within a particular period it is necessary to exogenously increase these payments between periods. Growth in real government consumption and transfer spending is also exogenously determined between periods, since within-period government spending is fixed in real terms.

The growth rates of all the remaining economic drivers, namely, government spending, foreign savings, world prices of both imports and exports, CPI, *etc*., are pre-determined.

For this study, the adopted Thurlow recursive dynamic CGE model transition equations are derived from behavioural relationships, historical growth trends or just exogenous fixation. They are dependent on the inter-period adjustments, which include population and labor force growth, capital accumulation, factor productivity changes, and change in government expenditure hence the transition equations for the capital stock, labour supply, population growth, factor productivity growth and the world prices. The updating equations determine how the exogenous variables and parameters relate-thus provide linkages between periods. For the specification of the factor supplies, factor productivity and population growth updating equations, see appendix C2.

4.11 Conclusion

This chapter presented the Thurlow (2004) recursive dynamic CGE model considered for this study. The model is divided into two components; the static component and the dynamic sub-model. With model specification, the subsequent chapter provides an outline of how the model is implemented and sets up the policy simulations.

CHAPTER 5

MODEL IMPLEMENTATION

5.1 Introduction

The adopted Thurlow recursive dynamic original model version was developed to allow for; (i) the regional disaggregation of international trade; (ii) an upward-sloping factor supply curve; and (iii) factor-specific productivity adjustments. For this study, the static module was restored back to the original IFPRI static model version while the dynamic updating equations were adopted with some modifications. This entails deletion of the adjusted and new equations added to the Thurlow static model version. A number of equations and updating procedures version are incorporated in the Thurlow model to extend the static module to a recursive dynamic module. The model was implemented by Thurlow (2004) in GAMS using calibration method (as described in Appendix E1).

This chapter is outlined as follows; the next section outlines the study data sources; section 5.3 sets the design of simulations; 5.4 presents the model simulation closure rules and 5.5 concludes the chapter.

5.2 The Databases

For this case, the Thurlow, (2004) recursive dynamic CGE model was parameterized to Botswana database. Three types of database are used to calibrate the model; the SAM database for the Botswana economy in the base-year 2011- recorded all transactions in the Botswana economy; behavioural parameters (thus elasticities) - that control the operation of the model's behavioural functions and; information set on exogenous variables and parameters of the dynamic sub-model. The following sub-sections focuses on documenting the collection of these databases.

5.2.1 The SAM Database

The model is parameterized and initialized to the modified version of the 2011 Botswana economy SAM built by EcoMod Network for the Ministry of Finance and Economic Development (MFED) in 2015- hereafter referred to as MODSAM2011. The MODSAM2011 is chosen because it is the latest Botswana SAM produced and used which was originally constructed with the support of Botswana Modelling and Forecasting Group chaired by the MFED. Additionally, the choice of the SAM was influenced by the fact that the MODSAM2011 conforms to the standard SAM for the standard CGE model employed in this study though needing some few adjustments which are explained later. A virtue of calibrating our CGE model to a MODSAM2011 database is the presupposition for its convenience and analytical consistency that is a characterisation of Botswana economy in its initial inter-temporal equilibrium in 2011.

The MODSAM2011 provides a considerably aggregated (from the original 2011 Botswana SAM) representation of sectors; there are 15 activities and 17 commodities. With the number of activities not equal to the number of commodities, this means one production activity can produces more than one commodity or one commodity can be produced by more than one production activity. However, the production activity with the same name as the commodity is the main producer of that commodity. Table 5.2 in appendix D2 shows the aggregation link between the initial and final SAM used in the model.

While aggregating the SAM, some few points were noted. Since the model analysis' focus is on the agricultural sector and on the income distribution amongst households, the MODSAM2011 was transformed and fairly aggregated to the proper format needed to sufficiently capture the links between the incomes of the households and the production sectors in which they are gained or between the expenditures of households and the activities which gain from them. The SAM aggregation took into consideration the key sectors of the Botswana economy which are, diamonds, copper (for BCL mine closer), and the government.

For the SAM database to be consistent with the model requirements, some adjustment attempts were made for the SAM to match the required format for inclusion in the standard CGE model. These tailoring procedures, which requires some adjustment and aggregation for our SAM to fit the standard CGE framework include;

a) Depreciation was allowed by adding it back to the net operating surplus to give gross operating surplus. The firms were now paid by the production factor capital the amount that includes allowance for depreciation.
b) Cognizant that the model does not accommodate for commodities imported for immediate re-exports, for the diamond mining activity which had this character-thus exporting more than what is producing, to curb this problem, for all its domestic factor use and intermediate inputs, were all aggregated to the diamond mining activity in the SAM which imports locally non-produced commodity and exports all of its output.

The modification and tailoring of the MODSAM2011 to a considerably condensed format furnished it with comprehensive and consistent information on crucial variables including; (i) gross output levels and compositions of production; (ii) the factorial value added; and, (iii) the distribution of income among the different institutions, especially different household groups. This makes the SAM to unravel a great deal about the interdependencies and structural features of the 2011 Botswana economy. It also furnishes sufficient information profiling the diversity in production sectors and the interdependencies among the various economic sectors and institutions characterizing the world's largest diamond producer.

The Botswana Macro SAM is presented Table 5.2 in the Appendix D1.

5.2.2: Behavioural Parameter Values of the Model

Cognizant that the SAM does not provide all the information required by the CGE model, it is a standard practice in CGE modelling that this required data (behavioural values) is econometrically estimated and then later imposed onto the CGE models. For production elasticities, the study adopted the econometrically estimated elasticities by Odada and Mogotsi (2000). For production factor elasticities at the top level, livestock and other agriculture sector elasticities were set at 0.93, for all mining sectors elasticities were set at 1.35,, manufacturing and construction at 0.75 and 0.91 respectively. The rest of other sectors elasticities were set at 1.06. For production elasticities at the bottom level, the elasticity of factor substitution was set at 0.60 across all sectors. The elasticities for the LES functions are taken from the BotsMod model.

The consumption elasticities are captured through the household income which is adopted from the BotsMod which originate from the USDA database collected in 1996. For livestock and other agriculture commodities, all households (cities, urban and rural) consumption elasticities were set at 0.5, for mining commodities at 0.7 while for the rest of other commodities the consumption elasticities across households was set at 0.8.

Trade elasticities for the model are from the BotsMod which also originate from the USDA database collected in 1996. Both the Armington substitution and Armington transformation elasticities were set at 0.8 for livestock, other agriculture, all mining commodities, petrol and manufacturing and 0.6 for the rest of other commodities.

5.2.3 Dynamic Data

In updating the dynamic module of our model, the used data included; (i) the observed and projected growth rates of sectoral value added- supplied by the Macro-economic Policy Section of MFED, and (ii) of government consumption- figures for the period 2011-2019 were taken from the Gross Domestic Product Quarter 1 published by Statistics Botswana (2020); (iii) projected population growth- came from Botswana Population Projections 2011-2026 published by Statistics Botswana (2015), (iii) factor accumulations (labour by each skill type, etc.); and depreciation rate- assuming fixed incremental capital-output ratio (ICOR), ICOR is set at 4 in the baseline scenario and is from World Bank's (2010) and finally the fixed capital is assumed to depreciate at a rate of 7 percent per annum for all activities . The labour supply by each skill type and subsistence consumption were assumed to grow at the same annual rate of population growth of 1.3 percent. Table 5.3 in Appendix E reports the targeted annual growth rates of sectoral value added imposed on the model to get a feasible solution.

5.3 Design of Simulations

Adjunct Botswana policies which seek to build on the potential of the livestock sector, livestock productivity improvement policy is plausible. To increase livestock productivity- two simulations were undertaken with the recursive dynamic CGE model. These two simulations are undertaken, before the Covid-19 effects, thus in an interrupted Botswana economy. The simulations entails; the baseline scenario which is interchangeably referred to as the reference or business-as-usual (BAU) scenario. The BAU is the simulation without the productivity gain in the livestock sector. The aim of the BAU is to trace the economy performance without the shock. The other simulation is with a specific disturbance/ shock on the model economy (counterfactual policy experiment) i.e with the productivity gain in the livestock sector. Below is the detailed description of both the counterfactual policy experiment preceded by the construction of the baseline scenario.

5.3.1 Baseline Scenario

The derivation of the BAU scenario is considered one of the most vital steps in dynamic CGE modelling analysis, in particular, and in quantitative policy analysis in general. The BAU replicates the historical path or reflects how the economy is likely to perform in a future year in absence of a significant shock. In this paper, the BAU scenario identifies the growth trajectory of the Botswana economy without COVID-19 effects. The Thurlow (2004) dynamic CGE utilized a parsimonious and transparent approach-wherein was parameterised so that it replicates the historical path and/or reflects the likely state of Botswana economy in a future years. As mentioned earlier, the model utilized the SAM database for the year 2011 which is assumed to be the characterization of the Botswana economy in an initial intertemporal equilibrium in 2011 for convenience and analytical consistency. The BAU scenario was derived by first rendering sectoral value added growth rates the driver of the evolution of the economy during the eight-year period from 2011 to 2019. The model calibration run is designed such that its solutions return the observed sectoral value added growth rates for each year. In the calibration run closure rule, the calibration term *(QVAADJ)*, the sectoral value added growth rate, in the value added function below, is fixed while the sectoral factor productivity proportionality term *(ALPHAVAADJ)* is flexed. These monitor the resulting sectoral factor productivity growth proportionality term and review and, if needed, adjust the targeted sectoral value added calibration term.

$QVA_a = QVA0_a * QVAADJ_a$;where QVA_a is value added in activity. The value added growth rates are pre-determined and the productivity parameter, $ALPHAVAADJ_a$, for each production sector in the value added production function is permitted to adjust freely;

$$QVA_a = ALPHAVAADJ_a * Alphava_a^{va} * \left[\sum_f \delta_{f,a}^{va} * \left[ad_{f,a}^{vaf} * QF_{f,a} \right]^{-\rho_a^{va}} \right]^{\left(-\frac{1}{\rho_a^{va}}\right)},$$

where $alhphava_a^{va}$ and $ad_{f,a}^{vaf}$ are total factor and factor-specific productivity parameters and $\delta_{f,a}^{va}$ is share parameter for activity *a*.

In running the model, the model did not only return the sectoral value added of the targeted real growth rates but also produces plausible sectoral productivity parameter term values.

Secondly, all the non-mining activities sectoral value added are allowed to be influenced by factor accumulation, thus growth in capital and of each labour skill types, population growth, endogenous total factor productivity as well as government consumption growth supply changes. For the closure rule, the sectoral productivity parameter term is fixed at their calibration-run solution levels and the sectoral value-added calibration term (*QVAADJ*) is allowed to adjust. This permits to monitor real value added growth and if needed, adjust the sectoral productivity proportionality parameter terms until the model replicates the historical evolution and the outlook of the economy.

Upon re-running our recursive dynamic model, the model generated a sequence of equilibria that traced out the observed growth path of the Botswana economy from 2011 to 2019. The eight equilibria show the extent to which our model reproduces the Botswana economy historical path from 2011 to 2019 hence validating our recursive dynamic CGE model. The model runs provide an extensive output that allowed computation of most macro-economic indicators such as real GDP at market prices and at factor costs, private consumption, total employment, etc., and the levels and patterns of sectoral production, trade, employment, consumption and household incomes, commodities and factor prices, government budget, *etc*. It is worth noting that our model calibration runs closure rules with the exception for those of mining sectors, responds to policy-independent or policy-induced disturbances is the reference scenario- reproducing only a series of static equilibria.

5.3.2 Counter-factual Simulation Design

The primary objective of this paper is to gain insights into the impact of productivity growth using CGE modelling framework.

The question that immediately arises is how to implement livestock productivity stimulus. For practical purposes, advancement in livestock farming technology is assumed to be Hicks-neutral. Therefore, it is implemented straight-forwardly by increasing the scale parameter (α_a^a) in the CES production function for the value added of the livestock sector from its value in the BAU scenario. Specifically, the efficiency at which livestock farmers combine factors of production – capital and labour – is increased by 5 percent. This simulation enables the livestock sector to produce more value added with each production unit than prior to productivity growth. Owing to the dearth of information on the mapping between investment expenditures and livestock productivity stimulus, the investment expenditures necessary for realising this policy initiative is assumed to have been undertaken prior to the current policy experiment. Therefore, no attempt has been undertaken to quantify the costs necessary for realising this policy initiative. In this policy scenario, the Hicks-neutral productivity stimulus is simulated under the default model set-up and parameter values. Note that a 5% Hicks-neutral productivity stimulus is an *ad hoc* assumption for illustrative purposes only, i.e., it is not based on any explicit policy goal. A 5% livestock productivity increase (SIM1) may be feasible over a short-period due to the underdeveloped nature of livestock production practices of Botswana.

The experiment design is shown below;

alphavalivestocksim('alphava',YR)$(NOT YR1(YR)) = 1.05*alphava0('clivestock'),

Where *alphavasim* is a parameter that carry the change(s) the level of livestock productivity (*alphava*) and *alphava*0 is the initial level of livestock productivity parameter. The model is then re-run using the new level of livestock productivity parameter parallel to the unchanged levels of all other exogenous variables to solve for a new sequence of equilibria solution values of the endogenous variables. For this counterfactual simulation, the model reproduced an alternative dynamic path which reflects the deviation of values of the aggregate and sectoral indicators from the dynamic reference path.

5.4 Simulation Closure Rules

For a model to have a solution, a necessary condition is that, it must be square, thus the number of equations must equal the number of variables. Should the problem of a number of variables be more than that of equations, the extra variables are fixed to equate them to the number of equations. This process of fixing the variables to render the system square is called the model closure rules. Furthermore, the model closure rules permits the mechanisms of the economy modelled to satisfy the real (domestic commodity and factor markets) and the nominal three macro balances; (the government (current) balance, savings-investment balance and external balance) system wide constraints not considered by the individual agents.

To reflect the Botswana economy realistically, the model imposed the following closure rules for the baseline scenario; for the government account, government savings is treated as a flexible residual while tax rates and government demand are fixed. This is to allow for policy changes with respect to each tax instrument, government consumption volume adjustment and government savings variations. For the foreign balance closure rule, foreign savings are fixed while real exchange rate is treated as flexible. This closure rule ensures that the domestic value of foreign currency receipts match the local currency outflows. In the savings-investment balance, the Botswana economy is assumed to be savings driven-thus the value of investment adjusts. The savings-driven closure rule commands that all non-government institutions savings rates be fixed while capital formation is flexible. The marginal propensities of non-government institutions are fixed and investment responds to changes in savings. In ensuring that the cost of investment equals the value of savings, each of commodity quantities in the investment bundle is multiplied by a flexible scalar.

In the factor market, capital is assumed to be fully employed and activity specific. This implies that capital is modelled as relatively scarce and immobile across sectors. In respect to the labour market, unskilled and semi-skilled labour types are modelled as perfectly elastic and supplied at their respective prevailing economy-wide wage rates, i.e., their wage rates are fixed and employment adjust. On the other hand, other labour types (professionals, manager, etc.,) are inter-sectoral mobile and are fully employed, thus their supply is fixed at flexible wage rates. Cognizant the relative importance of Botswana diamonds in the global diamonds market, the mining closure rule imposes that employment of both labour and capital in the mining sector be fixed while the factor-specific wage distortion variables be flexible.

Finally, the consumer price index (CPI) is the numeraire and is fixed at its base. This is for the reason that no evidence show Botswana to suffer from money illusion. The implication is all prices are defined relative to the CPI. This therefore provides a reliable test on calibration: a doubling of the CPI should leave all quantities demanded and supplied unaffected, but doubles all nominal variables, thus commodity and factor prices, incomes, etc. (Tlhalefang, 2019). This indicates that supply and demand functions are linearly homogenous or that optimisers respond to relative price changes.

5.5 Conclusion

The chapter described how the recursive dynamic CGE model was parameterized to Botswana databases. The chapter also presented the design of simulations needed to accomplish the study objectives. The next chapter is designated to present the study simulation results.

CHAPTER 6

SIMULATION RESULTS

6.1 Introduction

The purpose of this chapter is to present the simulation results undertaken using the Thurlow (2004) recursive dynamic CGE model. The model is solved in GAMS as a mixed complimentary problem (MCP) with PATH solver. The solution results are then exported from GAMS to excel spreadsheet for formal presentation of selected variables relevant to the study objectives. The first section reports the baseline scenario results. Unlike in the comparative static CGE models where counterfactual analysis is done with reference to the base run represented by the initial SAM, in the dynamic models, the economy also grows with no policy shock and the analysis is made with reference to the growth path in the absence of no shock.

The chapter is structured as follows; section 6.2 presents the baseline simulation results and section 6.3 presents the counterfactual results of the study. The sub-section 6.3.1 reports the macroeconomic results, 6.3.2 reports the sectoral results, 6.3.3 reports employment results and 6.3.4 presents the household income results. The last two sections, section 6.4 and 6.5 presents the sensitivity results and chapter conclusion respectively.

6.2 Baseline Simulation Results

This section reports the baseline results. The baseline essentially targeted to reflect how the economy would look like without the livestock productivity shock. The model baseline results were derived using the parsimonious and transparent approach wherein dynamic CGE model parameters are parameterized so that the CGE model reproduces the historical path and/ or reflects the likely state of an economy in the future year(s). The study recursive dynamic CGE model's reference scenario is derived under the design that sectoral value added for each of the non-mining sectors are responsive to factor accumulation and other growth drivers whilst value added of each of the mining activities respond whereas the sectoral productivity proportionality grow at the respective targeted rates. This is to assure the model returns the solution of the historical and projected growth rates of sectoral value added for each year The BAU results are presented and analysed below.

The baseline simulation results of selected macroeconomic indicators show a close similitude of the model real GDP growth rates and the historical and projected rates. For the period of 2011 to 2019, the Botswana economy grew at an average annual GDP growth rate of 4.3 percent for the observed period. The model then produced an average annual GDP growth rate of 4.37 percent giving a difference of 0.07 percent from the actual observed GDP growth rate. This notably indicates that our model reasonably tracks the historical performance between 2011 and 2019. Additionally, this provides basis that our model generates the BAU scenario that realistically approximates the evolution of the Botswana economy during this targeted eight-year period time horizon, 2011-2019.

Table 6.1: Sectoral Annual Average Growth Rates

Sector	Observed and Projected Sectoral Value Added Growth Rates	Model Baseline	Difference
livestock	0.75	1.79	1.04
Other Agriculture	1.72	1.28	-0.44
Diamonds	1.84	22.45	20.61
Copper	-8.62	3.2	11.83
Other Mining	2.02	1.67	-0.35
Manufacturing	3.78	8.42	4.65
Construction	6.71	8.13	1.42
Retail and Wholesale	15.11	8.64	-6.47
Hotels and Restaurants	6.98	8.89	1.91
Other Trade	3.3	3.96	0.66
Road Transport	6.09	1.5	-4.59
Other Transport	6.09	5.88	-0.21
Business Services	4.93	19.28	14.35
Government Services	3.62	22.35	18.73
Social Services	4.85	8.12	3.26

Source: Model simulation

Table 6.1 above shows the observed and projected annual average sectoral value added growth rates in compared with the baseline annual average sectoral value added growth rates generated from the model. As depicted in the table above, the model baseline results gave a close similitude results to the observed and projected sectoral value added growth rates. For example, the livestock sector had an annual average growth rate of 0.75 percent for the targeted observed historical period and the model generated a 1.79 percent growth rate giving a difference of 1.04 percent. Other sectors; other agriculture, other mining, construction, hotels and restaurants, other trade, other transport and social services initial growth rates gave a difference of -0.44 percent, -0.35 percent, 1.42 percent, 1.91 percent, 0.66 percent, -0.21 percent and 3.26 percent respectively. These results show our model to be reproducing the historical path and reflecting the likely state of the Botswana economy for the targeted period.

6.3 Counterfactual Results

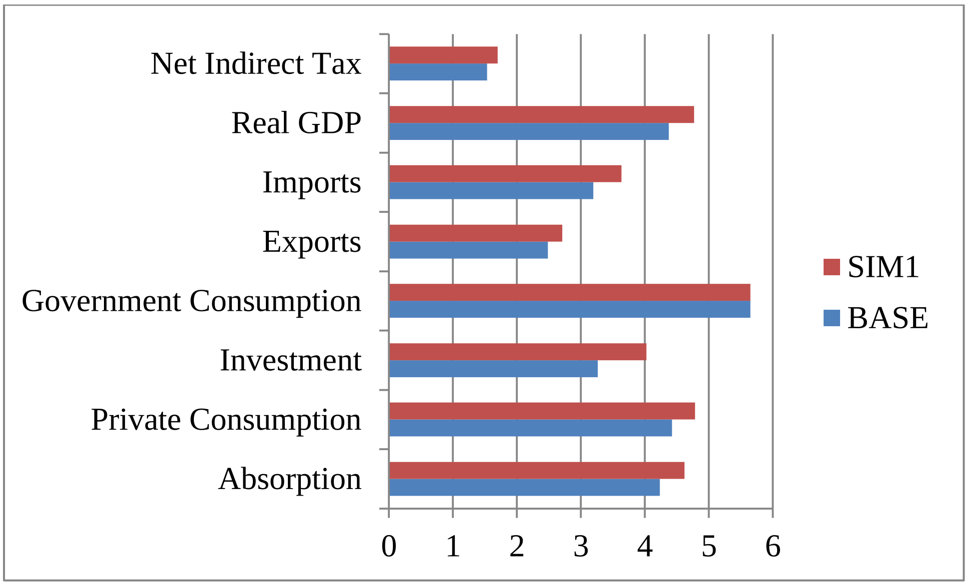
The counterfactual results are analysed by a paired comparison of the values of selected indicators for the reference scenario. The difference between the BAU values and the counterfactual scenario values (reported in percentages) are taken solely as the impact of the 5 percent increase in livestock productivity shock (SIM1). However, it must be noted that this policy shock is only applied to the livestock sector while the rest of other sectors are let to follow the baseline trend.

As a beneficial supply-side shock, a 5 percent increase in the livestock-sector's technical progress is expected to reduce the relative price of factor services, as measured in efficiency units, in the livestock sector. As a result, the relative prices of livestock products and those of industries that are intensive-consumers of livestock products, for example, food processing sectors, should fall. This mechanism should manifest itself in broad-based and sustainable economic development. The key question is: how large are the potential welfare benefits of the improve-livestock-productivity initiative likely to be for a 5% productivity growth and how are these gains or losses likely to be distributed across economic sectors in the case of Botswana? The following sub-section presents the livestock productivity increase impact on key macroeconomic indicators.

6.3.1 Impact on Macroeconomic Indicators

Figure 6.1 below presents the 5 percent livestock productivity stimulus effect on macroeconomic indicators. The results show varied impacts on growth in GDP, private consumption, investment, imports, exports and absorption. Since the Botswana economy is in general equilibrium prior to the Hicks-neutral technological progress, these effects are attributable to advancement in livestock farming technology.

Figure 6.1: Effects on Macroeconomic Indicators (%)



Source: Model Results

GDP is a key macroeconomic variable in measuring the wealth of the economy. It provides insight into whether the shock was detrimental or beneficial to the growth of the economy. From the livestock productivity increase shock, the economy experienced an annual growth rate of 4.77 percent compared to 4.37 percent in the baseline scenario giving a difference of 0.40 percent. This implies that, the livestock productivity increase is capable of raising the efficiency of aggregate output quantities-thus an increase in the level of economic activity. These study results conquers with those of Gelan *et al*., (2012), Gelan *et al*., (2013) and Engida *et al*., (2015), which revealed that, livestock sector productivity improvement has larger aggregate economic efficiency gains.

Investment, as a component of GDP increased the most. It raised by 0.76 percent. The growth in the investment reflects the reallocation of resources from non-productive sectors to productive livestock sector. By increase in livestock productivity this means an increase in the resources available for investment in this productive sector. As the accelerator theory stipulates, an improvement in the business factor income and economic forecasts will trigger an increase in its investment in order to meet future increment in demand. Thus to say, if factor incomes increases through the improvement of livestock productivity, as the economy is on an up-turn, this induces investment spending in the economy to rise.

After investment are imports with an average annual percentage increase of 0.44. The expansion in imports results can be explained by the increment in factor income which resulted from the livestock sector productivity improvement through additional increase in foreign exchange revenue since beef, beef by-products and hides& skins (livestock commodities) are the only exported agricultural commodities. With the country's poor crop production performance which led to low supply of food grain which its demands are therefore met through imports, the intuition is that foreign exchange earnings from the livestock export are used to purchasing more of import commodities necessary for other sectors of the economy. Thus the rise in factor income, ceteris paribus, increases the volume of domestic imports.

Conversely, exports, as a share in GDP, also experienced an average annual increase of 0.22 percent. Beef as livestock industry is Botswana's only agricultural exports; its expansion raises the beef exports to the EU market. This is due to the depreciation of real exchange rate (thus an average of 0.01 percent). From the domestic producers (livestock farmers) viewpoint, depreciation in real exchange enhances the price of exports relative to the domestic market price. The producers' thus then shift their optimal profit-maximizing output between export and domestic market production in favour of exports. The depreciation of real exchange rate makes exports cheaper in the world market inducing firms to export more. For our policy shock, depreciation of real exchange rate therefore favours the beef export performance.

With imports having grown more than exports following the depreciation of foreign exchange rate from the livestock productivity increase policy, the implication is that, with Botswana high dependence on imports, the increase in exports earnings are not big enough to offset the reduction in imports demand.

Despite the country's imports having increased more than exports, trade deficit fell by 0.24 percent yearly. The economic theory presents depreciation of domestic currency (real exchange rate) as one mechanism that can be used to correct for current account imbalances. This is in cognizance that a depreciation of the domestic currency (real exchange rate) will offer various advantages on the domestic economy; thus increases the incentive to sell more output in foreign markets than in the domestic markets; it also increases profits and encourages the production of export commodities. This implies that the domestic economy will now shift its production from non-tradable goods (domestic goods) to tradable goods (export goods) for higher returns.

The private consumption share in GDP is predicted to follow a rising trend. It increased by 0.36 percent. Private consumption is used synonymously to household final consumption expenditure so as to captures changes in household consumption, thus reflecting the extent to which changes in GDP growth are translated into household incomes. Our model of analysis assumes that households spend their income on consumption after paying taxes, saving and transfer to other institutions. The evaluation of the policy impacts on households consumption in this study is virtually important as literature has provided that most of the rural Batswana living in abject poverty derive at least most or in part of their food and income from livestock. The predicted growth in consumption value can be traced back to the sector performance analysis (as discussed in the later sub-section) which showed improvements in livestock productivity would lead to expansion and growth in the productive sectors; agriculture, manufacturing, other mining, hotels and restaurants and construction. In addition to the expanding livestock sector all these latter sectors serve to ensure labour factor categories find employment to help households diversify their income sources hence increase in their incomes and consumption expenditures. Delgado et al., (2001) also found that increase in livestock output leads to increased consumption.

A 5% livestock productivity growth improves aggregate welfare by 0.38 percent. As has been recommended to be a better measure of aggregate well-being by Arndt *et al*; (1995), the overall welfare has been quantified using real final domestic absorption. Domestic absorption is defined as the sum of real household consumption, government consumption and investment. This increase in the overall welfare is pronounced for households by an annual increase in private consumption (which measures household material welfare) by 0.36 percent. With the 5 percent livestock productivity increase translating into no effect in the government consumption, this clearly shows the household sector to be the main beneficiary of productivity increases. However, government savings increased (i.e increased by 0.84 percent).

The livestock productivity gain may have substantial dislocation effects on the micro-economy. Hence, it is worthwhile to explore its sectoral implications.

6.3.2 Sectoral Results

Following the macroeconomic impacts discussed in the previous section, however; represent aggregate impacts, it is informative to look at the microeconomic effects of the livestock productivity increase shock. This is in cognizance that the livestock sector growth effects are spread to other sectors of the economy by different linkages; production, employment and income. Table 6.2 below reports the impact of livestock productivity increase on the production sectors/ industries of the economy.

Table 6.2: Impact on Sectoral Outputs

Sector	Percentage Price Deviation From Base	Percentage Total Domestic Output Deviation From Base
Livestock	-8.56	1.76
Other Agriculture	0.07	0.33
Diamonds	1.63	0.21
Copper	0.03	-0.01
Other Mining	-0.04	0.77
Manufacturing	-0.43	1.61
Utilities	0.07	0.36
Construction	0.13	0.67
Wholesale& Retail	0.21	0.44
Hotels& Restaurants	0.03	0.68
Other Trade	0.25	0.42
Road Transport	0.21	0.1
Other Transport	0.19	0.33
Business	0.24	0.37
Government Services	0.43	-0.01
Social Services	-0.07	0.44

Source; Model Simulation

The results reveal that the effect on the sectors was diverse. All the sectors of the economy experienced a positive average annual output growth increase except for copper and government services activities. The livestock sector experienced the most annual output growth (1.76 percent) followed by manufacturing (1.61 percent). The latter two are the only sectors which registered a growth increase at least above 1 percent. Other mining, construction, hotels& restaurants experienced an annual growth rate above 0.5 percent, thus 0.77 percent, 0.67 percent and 0.68 percent respectively. The rest of the industries recorded below 0.5 percent. Other agriculture, diamonds, utilities, wholesale& retail, other trade, road transport and other transport recorded average percentage annual increase of 0.33, 0.21, 0.36, 0.44, 0.42, 0.1 and 0.33 respectively. The copper and the government services sector outputs were not impacted by the livestock productivity increase shock as the latter two industries registered relatively -0.1 percent and -0.01 percent annual output growth respectively.

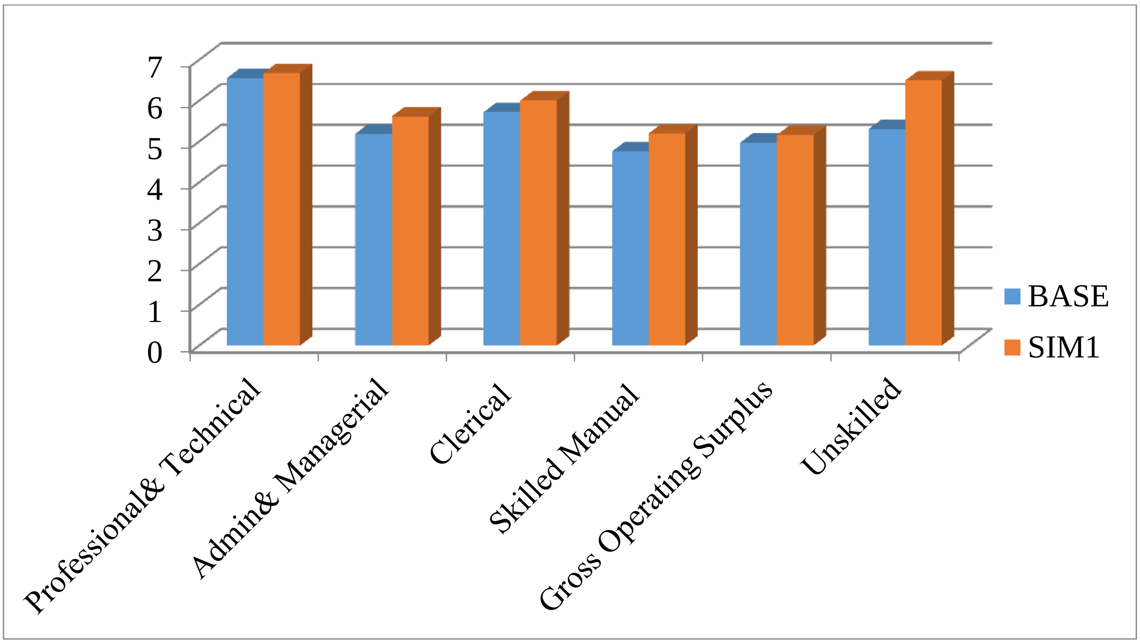
The output increase in the livestock sector, other mining, manufacturing and social services led to the reduction in their commodity prices by 8.56 percent, 0.04 percent, 0.43 percent and 0.07 percent respectively. For all other sectors, their prices increased with diamonds have experienced the highest increase of 1.63 percent while other remaining sectors had risen in price of lower than 0.5 percent with government high of 0.43 percent.

6.3.3 Effects on Employment

Employment generation is considered an important element for inclusive and job rich growth strategy (Gelaw, 2018). With the improvement in the livestock productivity policy, the focus is not only about growth but rather on ‘quality’ of growth through higher ‘participation effect.’ This is about jobs as well. Regarding the Botswana labour market with empirical and anecdotal evidence indicating a persistent high unemployment rate of the unskilled and semi-skilled labour types, which is common amongst the rural dwellers who happen to be densely populated within the agricultural sector, it is essential that we understand how employment reacts to the increase in livestock productivity shock. This will help evaluate our policy shock impacts on growth through employment opportunities. The results for the effects on employment presented in this section show the study policy shock to have positive impact across all sectors.

Figure 6.2 below reports the annual percentage change of factor employment relative to the baseline. The results indicate that an improvement in the livestock productivity brings about a rise in employment for all the factors.

Figure 6.2: Employment Effects



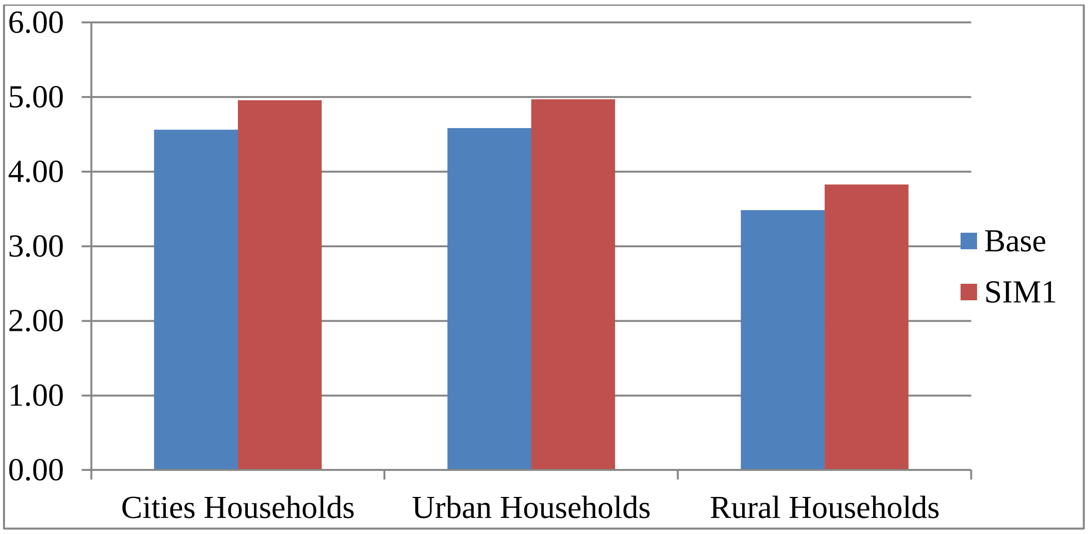
Source: Model Simulation

For the baseline simulation case, the professional& technical labour type grew the most, followed by clerical, then unskilled, administration& managerial, gross operating surplus and finally skilled manual labour type. However, for the counterfactual simulation case, after the professional& technical labour type was unskilled, then clerical, followed by administration& managerial, then skilled manual and finally gross operating surplus. For growth rates as percentage deviations from the baseline growth path, a 5 percent increase in the livestock productivity causes the highest increase for the unskilled labour type, followed by skilled manual labour type, then administration& managerial, clerical, gross operating surplus and finally the professional& technical labour type. The unskilled labour type employment rose by 1.19 percent. The skilled manual labour type employment grew by 0.44 percent, administration& managerial by 0.43 percent, clerical by 0.28 percent, while the gross operating surplus grew by 0.19 percent and lastly professional& technical labour type by 0.13 percent. As expected, the employment rate of the unskilled labour type increased the most. This is due to the fact that, with an increase in the livestock productivity, more of the unskilled labour-which is agriculture specific, is continually demanded due to rise in livestock output. The increase in demand for other labour type skills due the rise in livestock production and productivity, addresses the intuition that, now training is required for some jobs that previously required little or no training. This is because, with technological advancements, now jobs become more complex requiring more complex skills. These results are similar to those of Ibrahim et al., (2017) and Ali and Chaudhry (2015) who found that agricultural production improvement require agriculturalist skills improvement and education improvement respectively.

6.3.4 Implication of Livestock Sector Productivity on Household Income

The effect of livestock productivity increase on households' income is captured via its impact on factor income and income from transfers. This is in cognizance that the primary sources of households income originates from factor payments and transfers from other institutions. Figure 6.3 below therefore reports the results of the impact of livestock productivity improvement policy shock on households' income. The simulation results from the livestock productivity improvement effects show that household income across all households is higher than the baseline.

Figure 6.3: Implications on Household Income



Source: Model Simulation Results

For both the base and the simulation scenarios, income growth in cities and urban areas is found to be higher than that of the rural households. The cities and urban households have the largest income gain of 0.40 percent and 0.38 percent respectively. The rural households' income rise stood at 0.35 percent. The gain in the rural households' income can be as a result from the increase in the employment rate of the unskilled labour type (as shown in the previous section). This is because most of the rural people in Botswana generally have received no special training and has few specific skills, thus unskilled hence receiving their income from the unskilled type of labour.

With the macro results showing investment to increase most in the GDP components, and from the sectoral results, the unequal ownership distribution of capital between the rich and the poor can explain this unequal distribution of income too. From investment increase, towns/ cities' households deriving their livelihoods primarily from capital ownership-receiving a lion's share of around 63 percent while their rural dwellers counterparts receive only around 8 percent of net profits as shares, dividends and interest, as revealed by the SAM database, this therefore explains the larger increase in urban and cities households income than to rural households. Analogously, the rural households are found to be highly dependent on government with over 31 percent of their 2017's total income derived from government transfers, the government services sector decline in output therefore explains the lesser increase in rural households' income. With the urban and cities households owning higher shares of capital, this converts their total income mix to grow disproportionally higher than that of the rural households. Gelan et al., (2012); Gelan et al., (2013); Engida et al., (2015) results are also consistent with this study results as livestock sector productivity is found to lead to greater factor income growth-particularly labour income.

6.4 Sensitivity Analysis

While with the use of the calibration method in the development of the CGE models-method which allows the model to estimate with only one period of data rather than the econometric methods, CGE models are criticized for their inability to objectively test the robustness of the parameter estimates hence the simulation results. To check the CGE models robustness, the sensitivity analysis is conducted. The sensitivity is conducted for two purposes; (i) to test the robustness of the simulation results with respect to the assumed values for some key parameters; (ii) to provide a kind of 'confidence interval' for the simulation results, (Hosoe et al., 2010). There are several approaches to conducting sensitivity analysis. The most commonly used approach in CGE modelling entails the testing the effects of higher and lower values of selected parameters on the results (setting the elasticity at a lower and then higher values than the base values). The other method of carrying out sensitivity analysis is the Gaussian Quadrature method where the exogenous model variables are treated as dependent variables with associated distributions (Arndt, 1996). This enables the calculation of means and standard deviation for all model results. The other method advocated for by Harrison et al (1993), is more systematic sensitivity analyses. It requires systematic changes of key model parameters. However, for purposes of this study, the first method is used because of it is a straight-forward method to implement which is legible and easy to interpret its results.

Typically, the elasticities were varied individually. The sensitivity test involved changing the level of substitutability in the production function (thus varying the elasticity of substitution between labour and capital). With the Cobb-Douglas function giving a standard way of stating the production function, this study assumed the substitutability between production factors higher and the lower than in Cobb-Douglas (thus 1). This is the factor (labour and capital) substitution elasticity (σ_{22}) at the second level in the nested production structure. The simulations were then run singly with elasticities of substitution between factors of 0.3 and 1.4, i.e. 70 percent lower and 40 percent higher than the Cobb-Douglas elasticity. For the initial simulation case, the elasticity parameter was set at 0.6. The simulation results are qualitatively robust if alternate values of a given parameter do not influence the signs on the results and quantitatively robust if the differences in the scales of the impacts are not appreciable across the elasticity values, (Tlhalefang, 2007).

The simulation results of both the changed substitutability factors values compared to the levels of the initial simulation case are reported in table 6.3 for macroeconomic indicators and in table 6.4 for sectors of the economy.

Table 6.3: Sensitivity Analysis Macroeconomic Results

	Capital and Labour Elasticities		
	Lower-Elasticity Case (0.3)	**Initial Simulation Case (0.6)**	**Higher-Elasticity Case(1.4)**
Private Consumption	0.281	0.113	0.781
Investment	0.232	1.352	1.398
Government Consumption	0	0	0
Exports	0.162	0.597	1.024
Imports	0.158	0.559	1.021
Real GDP	0.251	0.453	1.152

Source: Model Simulations

Table 6.3 reports the simulation results comparing the effects of the alternate (lower and higher simulation cases) with the initial simulation case elasticity values between the domestic production capital and labour on selected macroeconomic indicators. The following observations emerge from the results. First, the directions of change (signs) of each of the macroeconomic results are the same for all cases. This reflects that the macroeconomic results are qualitatively robust.

Second, the ordering of the impacts on all the macroeconomic indicators varied with variations in the elasticity values. For example, GDP at factor cost experienced a lower increase for low elasticity case and a higher increase for high elasticity case than for the initial simulation case elasticity values. This increase trend was observed across all other macroeconomic indicators except for government consumption which gave a value of 0 in all the three cases. For instance, the GDP at factor cost increased by 0.187 percent when the domestic capital/labour substitution elasticities were lowered to 0.3, 0.427 percent in the initial simulation case and by 0.839 percent for the high elasticity case. With the changes in the scales of the macroeconomic impacts not appreciable higher or lower than those of the base elasticity values, this implies that the scales of the macroeconomic impacts are quite robust to capital/labour substitution elasticity.

Table 6.4 below illustrates the effects of factor substitution elasticity on the economy's sectors' outputs.

Table 6.4: Sensitivity Analysis Sectoral Results

Sector	Capital and Labour Elasticities		
	Lower-Elasticity (0.3)	Initial Simulation	Higher-Elasticity (1.4)
Livestock	1.237	1.756	2.861
Other Agriculture	0.295	0.325	0.512
Diamonds	0.039	0.209	0.562
Copper	0	-0.006	0.086
Other Mining	0.371	0.77	1.905
Manufacturing	1.029	1.607	2.675
Utilities	0.101	0.358	1.057
Construction	0.171	0.673	1.382
Wholesale& Retail	0.164	0.444	1.131
Hotels & Restaurants	0.311	0.679	1.071
Other Trade	0.145	0.417	1.055
Road Transport	-0.021	0.097	0.556
Other Transport	0.097	0.327	0.788
Business	0.109	0.368	1.054
Government Services	-0.002	-0.005	0.003
Social Services	0.255	0.439	0.956

Source: Model Simulation

As can be seen in table 6.4 above which compares the impacts of the initial simulation case elasticity values with those of the alternate simulation case values of domestic production capital/labour substitution elasticities on the outputs, the signs did not change in almost of the activity output with variations in the elasticity values except for copper, road transport and government services. For copper, both for the low and high cases, the production structure changed, for road transport it only changed under the low elasticity value while for the government services, the production structure changed for high elasticity value. However, the order of the output changes among other sectors is maintained in all cases. It is therefore that, the sectoral outputs results are quantitatively robust to variations in key capital/labour substitution elasticity parameter. The overall impact of raising or reducing the elasticity of substitution values between factors of production suggest that factor substitution elasticity influences both the scale of sectoral output and the qualitative results.

6.5 Conclusions

This chapter set out to present both the baseline and counterfactual results from the increase in livestock productivity policy shock. These simulations carried out are as outlined/ set out in the previous chapter 5. The results showed the BAU scenario to realistically approximate the evolution of the Botswana economy during eight-year time horizon, 2011-2019, where the economy activity accelerated at an average annual rate of 4.37 percent compared to 4.3 percent of the actual. For the counterfactual simulation results, the macroeconomic and the sectoral results were reported. These counterfactual results were then compared with those of the BAU scenario to get the policy shock effects. The simulation results showed the same trend growth of GDP in both cases of baseline scenario and the simulation scenario with the counterfactual scenario rise higher than that of the baseline scenario. The counterfactual scenario experienced an increase higher than that of the baseline by 0.40 percent. The livestock sector is found to be of great importance in increasing Botswana macro measures of GDP.

All of the GDP components contributed positively with investment contributing the most to the GDP followed by imports, then absorption, private consumption, and finally exports. This implied that the livestock productivity shock is beneficial to the growth of the economy. A 5% livestock productivity growth improved both the overall economic growth, as measured by real gross domestic product and aggregate welfare measured by the real gross final domestic absorption. The welfare gain is disproportionally distributed across economic sectors ranging from a low of 0.0 percent for government to a high of 0.36 percent for the household sector. The economy trades at deficit with high increase in imports.

For sectoral outputs, all sectors had a positive average annual increase in outputs except for copper and government services which had a decline in output growth. Livestock and manufacturing had the highest increase while road transport had the least increase of all sectors that experienced a rise in sectoral output. The highest increase in output growth for livestock and manufacturing led to the high price reduction. However, other mining and social services also experienced a decline in average annual price growth.

For employment, the livestock sector productivity improvement increased the demand for all factor employment. The unskilled labour type demand grew the most than any other skill type. This is because the unskilled labour type is agriculture specific. However, the demand growth of other skills type implied training requirement for jobs which required little or no training due to technological advancements.

The implication of the livestock sector productivity on household incomes shows an increase for all households. However, the cities and urban households registered a higher income gain than their rural counterparts.

Finally, the study reported the sensitivity of the initial simulation case results and alternative values of factor substitution elasticity. For both the macroeconomic and sectoral results, for lower elasticity values, all the macroeconomic indicators and sectoral outputs declined and rose for the high elasticity case compared to the initial simulation case.

The overall effects of varying the elasticity of substitution between the production factors showed that the factor substitution elasticity influences both the scale of macroeconomic effects and sectoral effects. The sensitivity tests results also show the qualitative predictions to be robust to alternative values of the substitution elasticities.

CHAPTER 7

SUMMARY AND POLICY IMPLICATIONS

7.1 Introduction

This thesis set out to assess the livestock sector productivity improvement contribution to the Botswana economy in efforts to combat the country's economic challenges of rural poverty, income inequality, food insecurity and unemployment. The study used the recursive dynamic CGE model to achieve its objectives in order to provide recommendations that will assist policy makers and other stakeholders in making informed long-term decisions in overcoming the latter challenges.

It is therefore the purpose of this chapter to provide the summary and conclusions drawn from the results and further suggest the policy recommendations drawn from the results. The chapter continues by giving the limitations of the study and concludes by giving suggestions for future research work.

7.2 Summary and Conclusions

In achieving the study objective of assessing the impact of the livestock productivity increase to the Botswana economy, the Thurlow (2004) recursive dynamic CGE model was adopted. The model was implemented in the GAMS software as an MCP with PATH solver. The model was parameterized to the modified version of the 2011 Botswana economy SAM built by EcoMod Network for the MFED in 2015 and to the given behavioural parameter values.

Firstly, the study was mainly concerned with understanding the functioning of the economy of Botswana- with particular interest on the agricultural sector productivity increase contribution to the economic development of Botswana. This information eventually dictated the development of the utilized recursive dynamic CGE model, design of simulations and interpretations of the results. This necessitated the review the structure and performance of

Botswana economy; the country's trade sector; and the livestock sector performance. Despite the country's poor performance of the agricultural sector-particularly crop production, with majority of Batswana residing from the rural areas mostly dependent on agriculture for food, income and informal employment, improvement of livestock sector is viewed as one potential candidate to increase rural household incomes, create sustainable jobs and investment opportunities for these rural population and drive economic diversification away from a mineral-dependent economy.

The study therefore discussed the need and importance for assessing the increase in livestock productivity in a dynamic computable general equilibrium modelling to address the country's continued development challenges; rural poverty, inequality, food insecurity and unemployment despite its good economic growth. This was in cognizance that, the use of the partial equilibrium modelling approaches yielded results that overstate both sectoral and economy-wide impacts of productivity growth in agriculture because it ignores price transmissions and factor market linkages, hence the use of the CGE models which are able to capture these links and show how the benefits of agricultural productivity growth are dampened throughout the economy. This economy-wide framework as a result examined the macroeconomic and distributional consequences of increase in livestock productivity shock on the Botswana economy. Through this, simultaneous quantitative expressions (simulations) were provided to indicate how macro-economic indicators such as GDP, investment, private consumption, etc., and how the level and sectoral output, exports, imports, employment, investment, etc. were affected by the external shock in the targeted eight-year period, 2011-2019.

From the descriptive analysis of the Botswana economy, the following stylised facts about the economy of Botswana. The country's economy being diamond and public-sector driven, the income gains, particularly from diamond production, do not get distributed as evenly as from other sectors such as agriculture hence not contributing much to poverty alleviation and food security, (FAO, 2014). The agricultural sector therefore is identified as one of the potential sectors for economic transformation due to its potential for growth, trade, and job creation according to the Botswana 2020/21 budget speech. However, within the agricultural sector, crop production, which is predominantly traditional, is risky to practice due to the semi-arid nature of the country. Cognizant that many Batswana households derive their livelihoods directly from agriculture (depend on it for food, income and informal employment), livestock production, for its advantages over other agricultural sectors and is an entry point for promoting gender balance in rural areas as; (a) almost household members have access to livestock and are involved in production; (b) livestock activities are a daily occupation; (c) livestock production systems offer the potential for introducing a wide range of project activities relating to gender mainstreaming, is found to be a door way to alleviating poverty, food insecurity, reducing income inequality and unemployment.

However, a number of key findings were identified in terms of the policy-modelling debate as well as deduced from the CGE simulation results. The main findings from the livestock productivity increase policy-adjusted scenario were that, the policy shock has a positive impact on the growth of the overall economy. The results showed the BAU scenario to realistically approximate the evolution of the Botswana economy during eight-year time horizon, 2011-2019, where the economy activity accelerated at an average annual rate of 4.37 percent as compared to the 4.3 percent of the actual GDP growth rate. For the counterfactual simulation results, the macroeconomic and the sectoral results were reported. These counterfactual results were then compared with those of the BAU scenario to get the policy shock effects. The policy shock was found to have a positive impact on the entire economy in general-increase in GDP. This implies that, the livestock productivity increase is capable of raising the efficiency of aggregate output quantities.

Of the GDP components, investment is found to contribute the most share to the GDP followed by imports, then absorption, private consumption share and finally exports. The livestock productivity increase did not have any effect to the government expenditure. The increase in investment due to increase in livestock productivity signifies the improvement in the livestock sector factor income. The growth in the investment reflects the reallocation of resources from non-productive sectors to productive livestock sector. Alongside Schultz model, due to the fact that the Botswana agricultural sector has not yet raised its production to a level where there can no longer be any technological advancement that could cause an increase in agricultural output, or have an effect to the economy, we can therefore argue that, with the existence of unutilized resources, the Botswana agriculture assumes Schultz model.

However, with the increase in real GDP hence good economic forecast, the increase in investment therefore is required in order to meet the continued livestock output demand increment. Complimentarily, with the country's poor crop production performance which led to low supply of food grain which its demands are therefore met through imports, the intuition is the foreign earnings from the livestock export may be channelled to purchasing more of import commodities. This explains the increase in imports more than the increase in the exports.

An increase in private consumption (thus household final consumption expenditure) demonstrates that households turn to participate and gain more from livestock GDP growth. This growth originating from livestock sector improvement indicates to have a higher return in terms of poverty reduction (i.e. a higher 'participation effect') since poverty reduction does not only depend on the rate of the overall economic growth, but also on the ability of poor people to connect to that growth (i.e. the 'quality' of growth) (Christiaensen et al., 2006).

Additionally, the increase in the household consumption can be motivated by the expansion of sectors like livestock, manufacturing, other mining and social services which led to the reduction in their commodity prices. Cognizant the livestock productivity improvement proposed policy; this depicts the link between the livestock sector and the industrial sector. With the improvement in the livestock sector which then brings about the expansion of the capitalist sector-which increases the demand for food, it is incumbent that the growth of the livestock sector-producing food, will meet this capitalist food demand. This will therefore reduce the food price in terms of capitalist products, and so raises profits. Lower food prices, stimulated by technological change in agriculture, maintain low real wages in industrial sectors and thus foster investment and structural transformation, (Diao et al., 2006). Thus the fall in food prices would lower the cost of living; especially for low income households with high food consumption shares since these rural people are usually consumers and most qualify to work in the agricultural sector which provides food to the urban areas hence the fall in food price benefit them the most. Consequently this will improve food security and their overall welfare.

The 5 percent increase in livestock productivity enhanced the employment across all labour skills types. The most employment increase was experienced by the unskilled labour type which is found mostly among the rural dwellers-thus agriculture centred. The policy therefore promoted employment.

The sensitivity analyses results showed both the quantitative and the qualitative results to be generally robust. The overall effects of changing the elasticity of substitution between the domestic production capital/labour factors demonstrated that factor substitution elasticity influences both the scale and the qualitative results of both the macroeconomic effects and sectoral outputs.

7.3 Policy Implications

Following the study results, the following policy implications are worth noting;

The study simulation results show that, improvement in livestock productivity appears to be a plausible and appealing choice for policy makers in promoting the country's economic growth, reducing poverty, income inequality and rural unemployment.

Notably, the proposed policy is found to raising the efficiency of aggregate output quantities- thus an increase in the level of economic activity. Moreover, livestock sector is found to be of great importance in increasing Botswana macro measures of GDP. In light of the Botswana NDP11, Vision 2036 and the Botswana 2020/21 Budget, it is imperative to continue efforts of improving the livestock productivity in the country as it offers advantages over other agricultural sectors and is an entry point for promoting balanced growth and also a driver of growth, especially in the early stages of industrialization.

The balance growth brought about the livestock proposed policy shows to bring a balanced growth where productivity gains are more evenly distributed across sub-sectors, something that is preferable. In Botswana, this entails investing more in expanding the livestock productivity. Furthermore, although livestock sector improvement causes a decline in the unskilled labour type income hence decline in poor households' factor income; it however improves their welfare through reduction in food prices which in turn lowers the cost of living ; especially for low income households with high food consumption shares since these rural people are usually consumers and most qualify to work in the agricultural sector which provides food to the urban areas hence the fall in food price benefit them the most. Consequently this will improve food security and their overall welfare.

Cognizant the latter, the government should continue efforts toward promoting livestock sectors growth as lack of its growth and diversification in the agricultural sector may accelerate rural-urban migration which will exacerbate the level of unemployment, food insecurity and urban poverty.

7.4 Limitations of the Study

This study results must be used taking into account the limitations in-built on the calibrated CGE models. Despite all good about the CGE modelling, also has, just like any other econometric models, its limitations. The CGE modelling fundamental problem that literature has extensively discussed is its overreliance on unrealistic neo-classical assumptions that is based upon which on the other hand raises a question of, is it realistic to model an economy with perfectly competitive markets, constant returns to scale, etc. Other scholars like Nyamadzabo (2004) criticized the CGE modelling arguing that the database the model is based on is from a specific year that is viewed to be at equilibrium which can be problematic if the base year was non-typical. The CGE models, for their behavioural parameters used in the model, are sometimes criticized that they are only the guesses having uncertain empirical foundations therefore their validation maybe insufficient on basis of the econometric estimations for other countries.

Abreast the existence proof of Walrasian general equilibrium by Arrow and Debreu and availability of algorithmic methods devised to compute Arrow-Debreu equilibria, Computable General Equilibrium (CGE) model (thus CGE models birth pinned on being computable and constructive), Velupillai (2006) and Velupillai and Zambelli (2010) are of different view that CGE models are neither computable nor constructive. The latter authors argued the genesis of the CGE models does not confront the conflict between the analytical and the constructive or the computable domains. Velupillai and associates adds that the CGE program remains unfinished because the passage to the limit is the non-constructive aspect of Brouwer's theorem which leaves no assurances that the sub-simplices determined by a fine grid of vectors on the [the price simplex] contains or is even close to a true fixed point of the mapping.

However, the fortes of the CGE modelling approach must also be appreciated. Thus, cognizant that CGE models are developed to address particular policy issues, they are not intended to be all-purpose models. It is worth noting that they can help identify the relationships in the economy, and the linkages that otherwise might be forgotten and therefore the results should always be analysed with limitations of the method in mind. Through the improvements in model specification, data availability, and computer technology, a CGE model with its system of equations derived from economic theory about the behaviour of different actors, with the simultaneous solution of the system, has been able to fulfil the general equilibrium, (Lofgren, Harris and Robinson, 2002).

One of their distinguishing features is that of in quantifying the effects of policy shocks and reforms, the CGE modelling has been seen as the only best option. This is due to the fact that, if there happens to be no previous experience of the future reform, which in econometrics is a requirement for valid results, there might not be any data to econometrically analyse the reform effects. Furthermore, CGE modelling has been widely used in the analysis of the continuous structural transformations taking place in some developing countries, meaning that sectors cannot be considered in isolation from one another, (Dervis et al., 1982).

Narrowing to the limitations of this study, though the 2011 Botswana economy SAM built by EcoMod Network for the Ministry of Finance and Economic Development in 2015 may be considered outdated, the latest SAM by MoFED was not available. Unlike for the 1996/97 Central Statistics Office (CSO) SAM which the livestock commodities account was disaggregated into two accounts; cattle and other livestock, the livestock account was aggregated into a single account. The SAM therefore does not have the livestock sector sub-model and its related additional databases which details the livestock economic accounts. This renders the SAM to lack a sub-matrix coming against the livestock activity accounts come from the livestock module and are reconciled with the economy-wide model through a complex relationship handled in the background within the herd dynamics model.

Further, the other agriculture account was also disaggregated into three accounts; fruits and vegetables, cereals and other agricultural products than as a single account as in our SAM case. The MODSAM2011 accounts aggregation therefore hinders the detailed analysis of the impacts of the livestock productivity improvements on different agricultural commodities.

7.5 Future Research Suggestions

As mentioned earlier, the MODSAM2011 used in this study does not capture in the specification of the livestock stock-flow linkages. This entails, as in Gelan et al., (2012) model, in formulation of the livestock sector sub-model and its related additional databases-thus detailing of the livestock economic accounts which are calculated revenues from off-takes of different livestock types and their products. Further, this will enhance the specification of the livestock stock-flow linkages in an economy-wide CGE model. This will enhance the novel feature of the establishment of firm links between stock and flows in the economic accounts which means having a biophysical stock account behind the economic flows represented in the SAM, (Gelan et al., 2012). This study therefore suggests future research to modify the EcoMod SAM to include a sub-matrix of the livestock economic accounts against the livestock activity accounts. This comes from the livestock module and is reconciled with the economy-wide model through a complex relationship handled in the background within the herd dynamics model. For such a framework, external shocks to the livestock production systems can be traced to the economic flows. Economic shocks that affect equilibrium relationships in the system of national accounts can also be traced back to the biophysical level. Specifying stock–flow linkages in this manner has rarely been implemented in economy-wide CGE models, (Gelan et al., 2012).

Moreover, the study did not recognize livestock capital as a factor of production in production sectors. The EcoMod SAM, in detailing the value addition of all factors of production and their contribution to household income, simply aggregated livestock capital together with other capital stock categories. In light of the fact that livestock capital plays a vital role in other agricultural activities, and crop production in particular, it is incumbent to account for livestock capital in the CGE model. It is therefore suggested that the future research take into consideration the sectoral gross value-added attributable to livestock capital.

Amidst the Covid-19 pandemic which continues to affect different sectors of many nations threatening food security and consequently food crisis, this study suggest future researches to incorporate Covid-19 impact in the model to gauge its impact on the results. the results then be compared with of the current study.

REFERENCES

Armington, P. (1969). "A Theory of Demand for Products Distinguished by Place of Production," IMF Staff Papers 16(1): 445-467

Arndt, C. *et al*., (2002), 'Parameter Estimation for a Computable General Equilibrium Model: A Maximum Entropy Approach', *Economic Modelling*, Vol. 19, pp. 375 – 398.

Arndt, *et al*., (1999), Marketing Margins and Agricultural Technology in Mozambique, Paper Presented at the Second Annual Conference on Global Economic analysis June 20-22, 1999.

Arndt, C., (1996), An Introduction to Systematic Sensitivity Analysis via Gaussian Quadrature. *GTAP Technical Paper, no. 02*.

Arrow, K.J. and Debreu, G. (1954). Existence of an Equilibrium for a Competitive Economy. *Econometrica,* Vol. 22. Pp. 265-290.

Bahta, S., Temoso, O. and Gatsoswe, K. (2018). Market channel choice decisions in Botswana's cattle markets. IN: Mtimet, N. and Dube, S. (eds.). 2018. International conference on livestock value chain finance and access to credit: Proceedings book from the livestock finance conference, Ezulwini, Swaziland, 21–23 February 2017. Nairobi, Kenya: ILRI: 222-233.

https://cgspace.cgiar.org/handle/10568/93416

Bahta S. Baker D. Podisi B. and Marobela O. (2015). Competitive smallholder Livestock in Botswana: Results of a livestock value chain survey in the Central district of Botswana. . Nairobi, Kenya: International Livestock Research Institute.

Bahta S. and Malope P. (2014). Measurement of competitiveness in smallholder livestock systems and emerging policy advocacy: An application to Botswana. Food Policy 49 (2014) 408-417.

Benin, S. Thurlow, J. Diao, X. Kebba, A. and Ofwondo, N. (2008). Agricultural Growth and Investment Options for Poverty Reduction in Uganda. IFPRI Discussion Paper 00790.

Development Strategy and Governance Division. International Food Policy Research Institute.

Botswana Investment and Trade Centre (BITC), (2017). Botswana Investors Handbook 2017.

Breisinger, C. Thomas, M. and Thurlow, J. (2010). Social Accounting Matrices and Multiplier Analysis: An Introduction with Exercises. Food Security in Practice. International Food Policy Research Institute.

Botswana Institute for Development Policy Analysis In association with GY Associates Ltd (2012). A Study of the Contribution of Sustainable Natural Resource Management to Economic Growth, Poverty Eradication and Achievement of NDP 10 Goals. Sector Assessments: Tourism & Agriculture. Submitted to: Ministry of Finance and Development Planning, Gaborone, Botswana.

Sadoulet, Elisabeth., and de Janvry, Alain. (1995). Quantitative Development Policy Analysis. The Johns Hopkins University Press. Baltimore and London.

Christiaensen, Luc., Demery, Lionel., and Kuhl, Jesper., (2006). The Role of Agriculture in Poverty Reduction: An Empirical Perspective. World Bank Policy Research Working Paper 4013, September 2006.

Christiaensen, Luc., Demery, Lionel., and Kuhl, Jesper., (2011). The (Evolving) Role of Agriculture in Poverty Reduction:An Empirical Perspective. Journal of Development Economics 96 (2011) 239–254.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S.,& Courbois, C. (1999). Livestock to 2020: The Next Food Revolution. Food, Agriculture and the Environment. Discussion Paper 28

Dercon, S., & Gollin, D. (2014). Agriculture in African Development: A Review of Theories and Strategies. CSAE Working Paper WPS/2014-22.

Dervis, K., de Melo, J., & Robinson, S. (1982). General Equilibrium Models for Development Policy. Washington, D.C.: A World Bank Research Publication.

Diao, Xinshen., Hazell, Peter., Resnick, Danielle., and Thurlow, James., (2006). The Role of Agriculture in Development: Implications for Sub-Saharan Africa. International Food Policy Research Institute (IFPRI). Development Strategy and Governance Division, Discussion Papper No.29.

Dwyer, L. Computable General Equilibrium Modelling: An Important Tool for Tourism Policy Analysis. Tourism and Hospitality Management, Vol. 21, No. 2, pp. 111-126, 2015.

Engida, E. Guthiga, P. Nyota, H. and Karugia, J. (2015). The Role of Livestock in the Kenyan Economy: Policy Analysis Using a Dynamic Computable General Equilibrium Model for Kenya. Regional Strategic Analysis and Knowledge Support System (ReSAKSS), Facilitated by IFPRI and ILRI. A Program in Support of CAADP Implementation. Working Paper No.37.

Frish, R. (1959). A complete schee for computing all direct and cross demand elasticities in a model with many sectors. Econometrica , 27(2): (177-196).

Gelan, A., Engida, E., Caria, A. S., & Karugia, J. (2012). The Role of Livestock in the Ethopian Economy:Policy Analysis Using a Dynamic Computable General Equilibrium Model for Ethiopia. International Association of Agricultural Economists (IAAE) Triennial Conference, (pp. 18-24). FOZ DO IGUACU, Brazil.

Girma, M. and Abebwa, D. (2012). Patterns and Determinants of Livestock Farmers' Choice of Marketing Channels: Micro-level Evidence. Ethiopian Economics Association Ethiopian Economics Policy Research Institute (EEA/EEPRI). Working Paper No 1/ 2012.

Hanson, Kenneth., & Rose, Adam., (1997).Factor Productivity and Income Inequality: A General Equilibrium Analysis. Applied Economics, 29:8, 1061-1071, DOI: 10.1080/000368497326453

Hosoe, N. Gasawa, K. and Hashimoto, H. (2010). Textbook of Computable General Equilibrium Modelling- Programming and Simulations. Palgrave Macmillan.

Ibrahim, A.A. Dahie, A.M. Addow, A.M. Muhummedarif, H. and Wasuge, B.A. The Role of Farming and Livestock Economic Development in Mogadishu, Somalia. International Educational Scientific Research Journal. E-ISSN NO : 2455-295X | VOLUME : 3 | ISSUE : 7 | JULY 2017.

International Fund for Agricultural Development (IFAD), (2010). Gender and Livestock: tools for Design. Livestock Thematic Papers- Tools for project design.

Irz, X., Lin, L., Thirtle, C., & Wiggins, S. (2001). Agricultural Productivity Growth and Poverty Alleviation. Development Policy Review, vol. 19, no. 4, pp. 449-466.

Johnston, B.F. and Mellor, J.W. (1961) 'The role of agriculture in economic development', American Economic Review, 51:566-593.

Jorgenson, D. W. (1961). The Development of a Dual Economy. Economic Journal.

Kabajulizi, Judith; (2016) Macroeconomic Implications Of Healthcare Financing Reforms: A Computable General Equilibrium Analysis Of Uganda. PhD thesis, London School of Hygiene & Tropical Medicine. DOI: https://doi.org/10.17037/PUBS.02545198

Kemi, A.O. (2016). Economic Impact of Livestock Production on the Society: A Case Study of Ikare Akoko Ondo State. IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS) e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 9, Issue 12 Ver. I (Dec. 2016), PP 77-80. www.iosrjournals.org

Lewis, W. A. (1954). Economic Development with unlimited supplies of labour. The Manchester School of Economics and Social Studies (22), 139-191

Lofgren, H. Haris, R.L. Robinson, S. with assistance from Thomas, M., and El-Sais, M. (2002). A Standard Computable General Equilibrium (CGE) Model in GAMS. *International Food Policy Research Institute.* Microcomputer in policy Research.

Lubungu M. Chapoto A. and Tembo Gelson. 2013. Smallholder Farmers Participation in Livestock Market in Zambia. Indaba Agricultural Policy Research Institute (IAPRI). Policy Brief. No. 60.

McDonald, S. (2001), Modelling Production in a Small Open Economy: CGE Model. The Practice of Models\Exercise 13. University Of Sheffield, UK.

Meijerink, G. & P. Roza. 2007. The role of agriculture in development. Markets, Chains and Sustainable Development Strategy and Policy Paper, no. 5. Stichting DLO: Wageningen. Available at: http://www.boci.wur.nl/UK/Publications/

Ministry of Finance and Economic Development (MFDP). (2010). National Development Plan 10. Gaborone: Government Of Botswana Publishers.

Ministry of Finance and Development Planning (MFDP). (2016). National Development Plan 11. Gaborone: Government Of Botswana Publishers.

Ministry of Finance and Development Planning (MFDP). (2020). *2020/21 Budget Speech*, Government of Botswana Publishers.

Mohora, M.C. (2006). RoMod: A Dynamic CGE Model for Romania- A Tool for Policy Analysis. Thesis to obtain the degree of Doctor from the Erasmus University Rotterdam by command of the rector magnificus Prof.dr. S.W.J. Lamberts and in accordance with the decision of the Doctorate Board.

Olsson, J. and Ohlund, E. (2004). Diamond Dependence and HIV/ AIDS- A CGE Analysis of the Economic Consequences for Botswana.Course 5210, Master Thesis in International Economics. Stockholm School of Economics, Sweden.

Overseas Development Institute, (2007). Analysis of the Economic and Social Effects of Botswana's Loss of Preferential Market Access for Beef Exports to the European Union.

Pauw, K., & Thurlow, J. (2011). Agricultural Growth, Poverty and Nutrition in Tanzania. Food Policy (36), 795-804.

Pyatt, G., (1988), ‘A SAM Approach to Modelling’, *Journal of Policy Modelling*, Vol. 10, no.3, pp. 327 - 352.

Ranis, G., & Fei, J. C. (1961). A Theory of Economic Development . American Economic Review, 535-565.

Rossouw, R. (2004). General Equilibrium Modelling in South Africa: An Overview and Appraisal. Thesis submitted for the degree Magister of Commerce in the School of Economics, Risk Management and International Trade at North West University (Potchefstroom Campus).

Schneider, Kate., and Gugerty, Mary Kay., (2011). Agricultural Productivity and Poverty Reduction: Linkages and Pathways. Evans School Policy Analysis and Research (EPAR). Abridged EPAR Brief No. 121. Prepared for the Agricultural Development Team of the Bill & Melinda Gates Foundation The Evans School Review. Vol. 1, Num. 1, Spring 2011

Schultz, T. W. (1964). Transfroming Traditional Agriculture. New Haven: Yale University Press.

Seleka, T.B. (2005). Challenges for Agricultural Diversification in Botswana Under the Proposed SADC-EU Economic Partnership Agreement (EPA). BIDPA Working Paper 27. ISBN: 99912-0-559-4

Statistics Botswana, (2018). Gross Domestic Product Quarter 3, 2018. December 2018.

Statistics Botswana, (2018). Botswana Multi-Topic Household Survey Report 2015/16. ISBN:978-99968-2-040-3. December 2018.

Statistics Botswana, (2018). Botswana Agricultural Census Report 2015. ISBN NO: 978-99968-418-3-5. June 2018

Statistics Botswana. (2015). Botswana Environment Statistics: Natural Disasters Digest. Gaborone: Statistics Botswana

Thurlow, J. (2004). A Dynamic Computable General Equilibrium (CGE) Model for South Africa: Extending the Static IFPRI Model. Pretoria: Trade and Industrial Policy Strategies (TIPS).

Thurlow, J. (2008). A Recursive Dynamic CGE Model and Microsimulation Poverty Modue for South Africa. Washington, D.C: International Food Policy Research Institute .

Thurlow, J., & van Seventer, D. E. (September 2002). A STANDARD COMPUTABLE GENERAL EQUILIBRIUM MODEL FOR SOUTH AFRICA. Washington, D.C. 20006, U.S.A.: Trade and Macroeconomics Division, International Food Policy Research Institute.

Timmer, C.P. (1988). The Agricultural Transformation. Handbook of Development Economics, Volume 1, Edited by H. Cheneo' and T.N. Srinivasan. Elsevier Science Publishers B.V.

Tlhalefang, J. (2019). Deriving a Baseline Scenario For Dynamic Computable General Equilibrium Model of Energy-Economy Interactions for Botswana. (Unpublished).

Tlhalefang, J. (2006). Computable General Equilibrium Implications of oil Shocks and Policy Responses in Botswana.

Tlhalefang, J. and Sebikiri, M. (2011). A CGE Analysis of the Potential Consequences of Higher Food Prices for the Botswana Economy. International Journal of Economics& Business Studies, Vol. 1, Issue 2, Pg 3- 13.

Tlhalefang, J.B. (2007), Computable General Equilibrium Implications of Oil Shocks and Policy Responses in Botswana, Unpublished PhD Thesis, The University of Sheffield.

Tsheko, B. (2002). The Potential Implications of the EU-CAP Reforms on the Botswana Beef Industry, www.jsd-africa.com/.../ARC Implications of the EU CAP Reforms. Pdf

Wobst, P. (2000). Why the Poor Care About Partial Versus the General Equilibrium Effects. Part I: Methodology and Country Case. Trade and Macroeconomics Division, International Food Policy Research Institute.

Xavier Irz & Lin Lin & Colin Thirtle & Steve Wiggins, 2001. "Agricultural Productivity Growth and Poverty Alleviation," Development Policy Review, Overseas Development Institute, vol. 19(4), pages 449-466, December.

Yorgason, V. W. (1972). Theories of Agriculture in Development.

APPENDICES

For appendices, see the attached

APPENDICES

Appendix A1

Table 4.1: Behavioral Relationships for Botswana standard CGE Model

	COMMODITIES	ACTIVITIES	FACTORS	HOUSEHOLDS	ENTERPRISES	GOVERN-MENT	CAPITAL ACCOUNTS	REST OF WORLD	TOTAL	PRICES
COMMODITIES	0	Leontief	0	Stone-Geary Utility Functions	Fixed in Real Terms	Fixed in Real Terms and Export Taxes	Fixed Savings Shares	Commodity Exports	Commodity Demand	Consumer goods Price Exports Prices
ACTIVITIES	Domestic Production	0	0	0	0	0	0	0	Production Functions	
FACTORS	0	Factor Demands (CES)	0	0	0	0	0	Factor Income From RoW	Factor Income	
HOUSEHOLDS	0	0	Fixed Shares of Factor Income	Fixed (Nominal) Transfers	Fixed (Nominal) Transfers	Fixed (Nominal) Transfers	0	Remittances	Household Income	
ENTERPRISES	0	0	Fixed Shares of Factor Income	0	0	Fixed (Nominal) Transfers	0	Transfers	Enterprises Income	
GOVERN-MENT	Tariff Revenue	Indirect Taxes	Fixed Shares of Factor Income	Direct Taxes on Household Income	Direct Taxes on Enterprises Income	0	0	Transfers	Government Income	
CAPITAL ACCOUNTS	0	0	0	Household Savings	Enterprises Savings	Government Savings	0	Current Account	Total Savings	
REST OF WORLD	Commodity Import	0	Fixed Shares of Factor Income	0	0	0	0	0	Total 'Spending' Abroad	
TOTAL	Commodity Supply	Activity Input	Factor Expenditure	Households Expenditure	Enterprises Expenditure	Government Expenditure	Total Investment	Total Income From ROW		
	Producer goods Prices, Domestic and World Prices of Imports	Value-added								

Source: McDonald, 2001

Appendix A2

Table 4.2: Transaction Relationship for the Standard Model

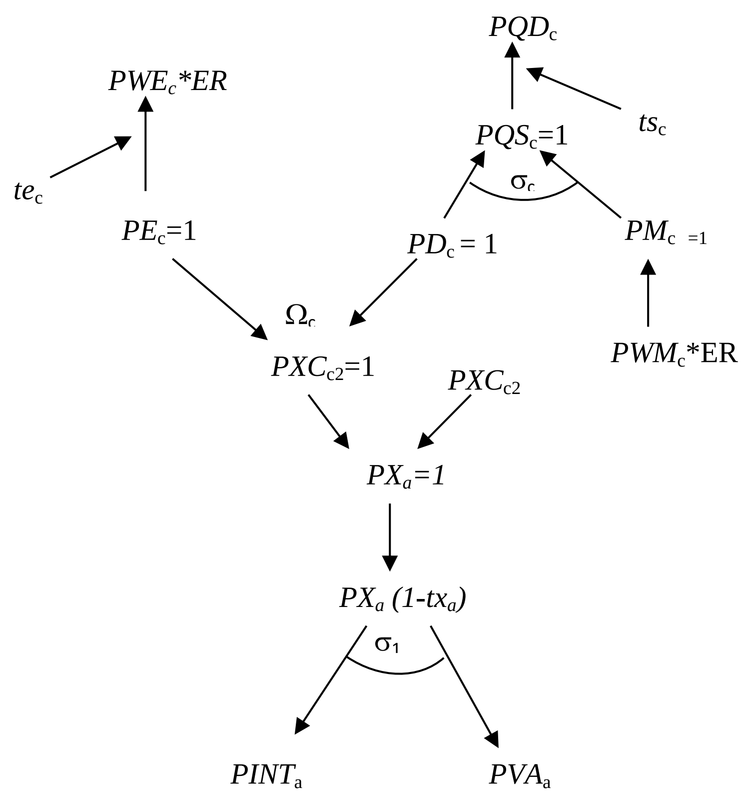
	Activities	Commodities	Factors	Households
Activities	0	$(PDOM_c \cdot QDOM_c), (PACT_a \cdot QACT_a)$	0	0
Commodities	$(PQDOM_c \cdot QINTDEM_c)$	0	0	$(PQDOM_c \cdot QHDEM_c)$
Factors	$(WFACT_{f,a} \cdot QFACT_{f,a})$	0	0	0
Households	0	0	$\left(\sum_f hxfactshare_{h,f} \cdot YFACT_f\right)$	$\left(\sum_{hh} hxhconst_{hh,h}\right)$
Enterprises	0	0	$\left(\sum_f entxvadshare_f \cdot YFACT_f\right)$	0
Government	$(tx_a \cdot PACT_a \cdot QACT_a)$	$(tm_c \cdot PWM_c \cdot QIMP_c \cdot EXR)$ $(te_c \cdot PWE_c \cdot QEXP_c \cdot EXR)$ $(ts_c \cdot PQS_c \cdot QQ_c)$ $(tec_c \cdot PQS_c \cdot QQ_c)$ $(tfuec_c \cdot PQS_c \cdot QQ_c)$	$\left(\sum_f govtvadshare_{,f} \cdot YFACT_f\right)$ $(facttax_f \cdot YFACT_f)$	$(dirty_h \cdot YHO_h)$
Capital	0	0	$\sum_f dep_f$	$(capsavhxh_h \cdot YHO_h)$
RoW	0	$PWM_c \cdot QIMP_c \cdot EXR$	$\left(\sum_f rowvadshare_f \cdot YFACT_f\right)$	0
Total	$(PACT_a \cdot QACT_a)$	$(PQDOM_c \cdot QQ_C)$	$YFACT_f$	YHO_h

Table 4.2 (continues)					
	Enterprises	**Government**	**Capital**	**RoW**	**Total**
Activities	0	0	0	0	$(PACT_a \cdot QACT_a)$
Commodities	$(PQDOM_c \cdot QENTEM_c)$	$(PQDOM_C \cdot QGOVTDEM_c)$	$(PQDOM_c \cdot QINVESTDEM_c)$, $(qdstkconst_c \cdot PQDOM_c)$	$PWE_c \cdot QEXP_c \cdot EXR$	$(PQDOM_c \cdot QQ_c)$
Factors	0	0	0	$factrow_f \cdot EXR$	$YFACT_f$
Households	$hxentconst_h$	$hxgovtconst_h \cdot HGOVTADJ$	0	$hxrow_h \cdot EXR$	YHO_f
Enterprises	0	$entxgovtconst \cdot EXGOVADJ$	0	$entxrow_h \cdot EXR$	$YENT$
Government	$(TYENTADJ \cdot dirtyent_e \cdot YENT)$	0	0	$govtxrow_h \cdot EXR$	$YGOVT$
Capital	$YENT - EENT$	$YGOVT - EXGOVT$	0	$CAPROW \cdot EXR$	$TOTSAVE$
ROW	0	0	0	0	$Total\ Expenditure\ Abroad$
Total	$YENT$	$YGOVT$	$INVEST$	$Total\ Income\ Abroad$	

Source: Mc Donald (2001)

Appendix A4

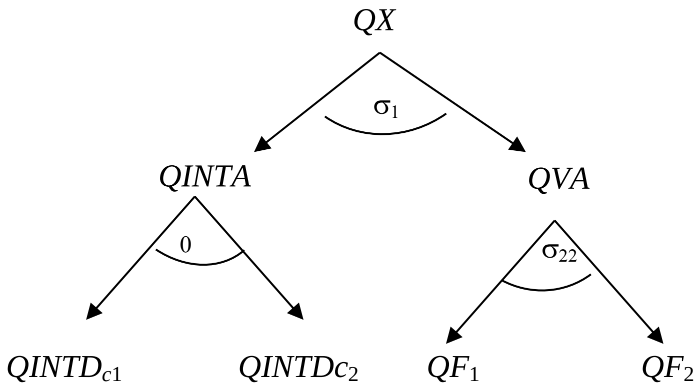
Figure 4.3: Price Relationships for the Standard CGE Model



Source: McDonald (2001)

Appendix A5

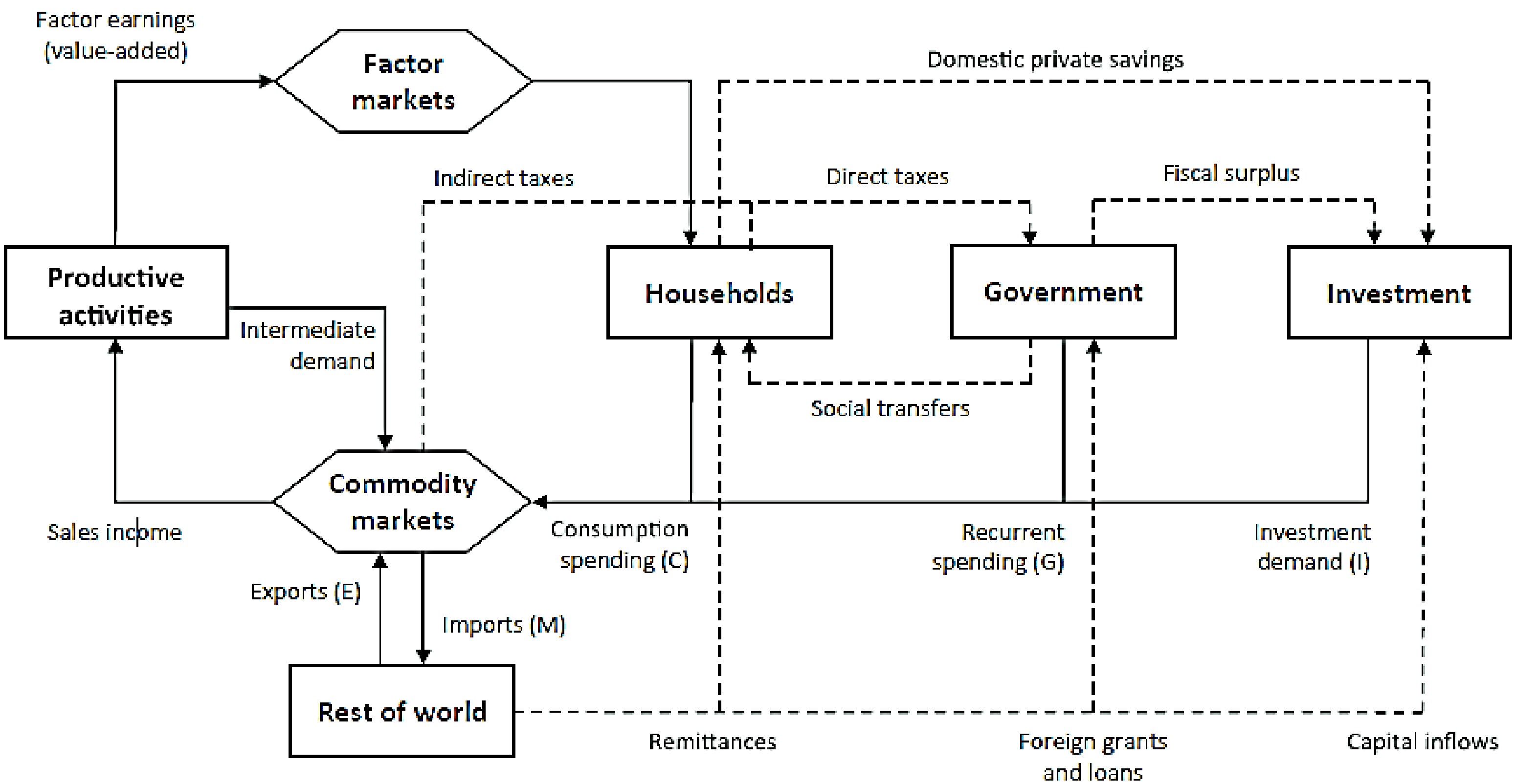
Figure 4.2: Nested Production Structure for Model in Quantities



Source: Tlhalefang, (2007)

Appendix B1

Figure 4.3: Circular flow diagram of the economy



Source: Breisinger, Thomas and Thurlow (2009)

Appendix B2

Table 4.7: An Outlay of the Basic Structure of a Macro SAM

	ACTIVITIES (C1)	COMMODITIES (C2)	FACTORS (C3)	HOUSEHOLDS (C4)	ENTERPRISES (C5)	GOVERNMENT (C6)	SAVINGS-INVESTMENT (C7)	REST OF WORLD (C8)	TOTAL
ACTIVITIES (R1)		Marketed Outputs		Home-Consumed outputs					Activity Income (Gross output)
COMMODITIES (R2)	Intermediate Inputs	Transaction costs		Private consumption		Government consumption	Investment	Export	Demand
FACTORS (R3)	Value Added							Factor Income From RoW	Factor Income
HOUSEHOLDS (R4)			Factor Income to households	Inter-household transfers	Surplus to households	Transfers to households		Transfers to households from RoW	Household Income
ENTERPRISES (R5)			Factor Income to enterprises			Transfers to enterprises		Transfers to enterprises from RoW	Enterprises Income
GOVERN-MENT (R6)	Producer taxes, value added tax	Sales taxes, tariffs, export taxes	Factor Income to government, factor taxes	Transfers to government, direct	Surplus to government, direct enterprises taxes			Transfers to Government from RoW	Government Income
SAVINGS-INVESTMENT (R7)				Household Savings	Enterprises Savings	Government Savings		Foreign Savings	Savings
REST OF WORLD (R8)		Imports	Factor Income to RoW		Surplus to RoW	Government transfers to RoW			Foreign exchange outflow
TOTAL	Activity	Supply Expenditures	Factor Expenditures	Households Expenditures	Enterprises Expenditures	Government Expenditures	Investment	Foreign exchange inflow	

Source: Lofgren (2002)

Appendix B3: ***Description of the Macro SAM***

The above table 4.7 in Appendix B2 depicts an aggregated standard SAM with verbal explanations in the cells instead of numbers providing all features required for implementation with the standard CGE model. First and foremost, it is worth noting that, unlike in the above standard SAM, taxes (divided into direct taxes-on domestic nongovernment institutions and factors, commodity sales taxes, import taxes, export taxes, activity taxes, and value-added taxes) are to be paid to tax accounts disaggregated by tax accounts, from which each account forwards its earned revenues to the core government. It is also worth noting that the standard SAM does not allow for payments in the blank cells of the matrix requiring a restructuring of any SAM including payments in such cells before implementation in the standard CGE. Further, the standard SAM allows for multiple accounts for activities, commodities, factors, and domestic non-governmental institutions which GAMS code can handle any desired disaggregation, including for a single account. In any real-world application, the preferred disaggregation of the SAM and the CGE model depends on data availability and the purposes of the analysis and it is typically preferable to include relatively detailed treatment in areas of interest while keeping the database relatively aggregated in other areas, (Lofgren *et al.*, 2002).

Activity Account: The activity account entities carry out production. The activities are separated from the commodities to permit for production of more than one kind commodities (by-products) to be produced from a single activity. Thus, for example, cattle may produce the commodities meat and hides& skins. These activities combine the factors of production with intermediate inputs to produce goods and services. Activities make payments to the factors in wages, rents and profits generated during the production process (thus, value added). Value added is also referred to as “GDP at factor cost.” It is the factors of production earnings. The value-added entry in the SAM is shown in the activity column and the factor row [R3-C1]. In the similar manner, intermediate demand which is the goods and services used in the production process, is a payment from activities to commodities [R2-C1]. These receipts are valued at producer prices (thus at farm or factory gate prices). Value added and intermediate demand together gives the gross out.

Commodity Account: Commodities are outputs from activities. Correspondingly, commodities are also separated from the activities as any commodity may be produced by multiple activities (for example maize commodity may be produced by both the small scale and large-scale maize farmers). The commodities are either supplied locally, exported, or imported. Valued at market prices (including indirect commodity taxes and transaction costs), payments are made to domestic activities, the rest of the world, and various tax accounts (for domestic and import taxes). The latter can be read from commodity column entries against other accounts rows in the SAM, [R1-C2], [R7-C2] and [R6-C2] respectively. The commodities' final demand comprises of household consumption spending [R2-C4], government consumption or recurrent expenditure [R2-C6], gross capital formation or investment [R2-C7], and export demand [R2-C7]. Separately, these are sometimes referred to as a "Supply–Use Table," or the total supply of commodities and their different kinds of uses or demands. The commodity domestic supply and imports segregation treatment provides data required for the perfect or imperfect substitutability between imports and domestic production modelling assumption.

In the activity and commodity accounts, there appears some transaction costs which in the standard SAM are referred to as marketing margins. These are the transaction (trade and transport) costs. From the SAM commodity account entry, these are the costs linked with domestic (cost of moving the commodity from the producer to the domestic demander), import (cost of moving the commodity from the border (adding to the c.i.f. price) to the domestic demander), and export (cost of moving the commodity from the producer to the border (reducing the price received by producers relative to the f.o.b. price)) marketing. Both the commodity and activity accounts information is normally published by the country's statistical bureau.

Households Account; these are usually the ultimate factors of production owners and the receive the incomes earned by factors during the production process [R4-C3]. Other sources of income for households include payments like social security and pensions from the government [R4-C6] and payments from the rest of the world such as remittances received from family members working abroad [R4-C8]. Households have expenditures they make to other institutions; direct tax payment to government [R6-C4] and commodity purchases [R2-C4]. This is the household consumption which the SAM distinguishes into home consumption (which is activity based hence valued at producer prices without marketing margins and the sales taxes that may be imposed on marketed commodities) and households' marketed consumption (which is commodity- based valued market prices inclusive of marketing margins costs and commodity taxes). However, the standard CGE model does accommodate a SAM without home consumption attribute. For the remaining income, households then save it (or dis-saved/borrows if expenditures exceed incomes) [R7-C4]. National accounts and household surveys from the country's statistics bureau usually provides data in household accounts.

Enterprises Account; like households, enterprises as owners of capital and/ or land, earn factor incomes [R5-C3] and also receive some transfer payments from other institutions. Their earned income is then used to pay direct taxes [R6-C5], savings [R7-C5] and transfers to other institutions like rest of world[R8-C5]. Unlike households, enterprises do not consume. In the standard SAM, enterprise accounts are not as much required and necessary as households.

Government Account; The standard SAM allows for the government account disaggregation into the core government account and different tax accounts, one for each tax type. This disaggregation helps in some economic interpretations of some payments which may otherwise be ambiguous. Any (or all) of the individual tax accounts may be excluded form the SAM for any given application. Any payments between the government and other institutions in the SAM are reserved for transfers.

The government earns its income from direct and indirect taxes. These include transfer payments from producer and value added taxes [R6-C1], sales, tariffs and export taxes [R6-C2], factor income and taxes to government [R6-C3], transfers to government [R6-C4], transferred surpluses from the enterprise sector [R6-C5], the rest of the world such as foreign grants, loans and development assistance [R6-C8]. This government earned revenue is then used to pay for recurrent consumption spending [R2-C6], transfers to enterprise [R5-C6], transfers to households [R4-C6], and government transfers to the rest of the world [R8-C6]. After paying all its expenditures, the remaining revenue forms the government fiscal surplus (or deficit, if expenditures exceed revenues) [R7-C6], defined by the difference between total revenues and expenditures. Most of the low-income country governments receive grants and loans from their development partners and foreign financial institutions in order to cover for recurrent spending and capital investments. These payments are directly paid to the government from the rest of the world. This foreign debt requires positive (but can also be treated as a negative receipt from the rest of the world) interest payments from the government to the rest of the world. The government accounts information is usually drawn from the public sector budgets by the country's ministry of finance.

Savings, investment, and the foreign account; the ex post accounting identity requires that investment or gross capital formation (which includes changes in stocks or inventories) be equal to total savings. Having accounted for private savings [R7-C4] and public savings [R7-C6], total capital inflows from abroad or current account balance [R7-C8] is given by the difference between total domestic savings and total investment demand (or dis-savings if expenditures exceed incomes).

This also reflects the difference between foreign exchange receipts (exports and foreign transfers received) and expenditures (imports and government transfers to foreigners) for the rest of the world and equates to the fiscal surplus/deficit for the government. The current account information is usually drawn from the balance of payments data publicly provided by a country's central bank while the government savings information is documented in the government budget and balance of payments.

Appendix C1

4.6 The Algebraic Statement and Equations of the Static CGE Model

From the behavioural relationships' statements, they are translated into a set of simultaneous linear and non-linear equations describing the flows represented in the SAM-thus giving a description of how the economy model functions. The model equations therefore describe the behaviour and interactions of these actors using rules captured by both fixed coefficients and non-linear first-order optimality conditions. To ensure that a set of both micro and macroeconomic constraints are satisfied, such that factor and commodity markets, savings and investment, and government and current account balance requirements are met.

In presenting the mathematical statement of the model, a necessary condition, that the model be square-thus number of equations equating number of variables, for a model solution to exist is met. This presentation and text being heavily drawn from the Lofgren *et al.*, (2002) model, the latter is not a sufficient condition but rather a necessary condition for existence of a different solution. The model equations are divided into price block, production and trade block, institution block, system constraint block. The sets (are declared with members assigned to them), parameters and variables (as names chosen to facilitate interpretation) utilised in this model are first defined, with commodity and factor quantities starting with q, commodity prices starting with p, and factor prices starting with w.

Below is a table giving a summary of the notational principle.

Table 4.1: Notational Principles

Item	**Notation**
Endogenous Variables	Upper-case Latin letters without a bar
Exogenous Variables	Upper-case Latin letters with a bar
Parameters	Lowe-case Latin letters (with or without a bar) or Lower-case Greek letter (with or without superscripts)
Set Indices	Lowe-case Latin letters as subscripts to variables and parameters
Notes	Exogenous variables are fixed in the basic model version but may be endogenous in versions with different treatment of macro- or factor-market closures.

Source: Lofgren *et al.*, (2002).

The sets, parameters and variables specified over commodities, activities, factors and institutions are defined below as per Lofgren *et al.*, (2002);

SETS

$\alpha \in A$ activities

$\alpha \in ACES(\subset A)$ activities with a CES at the top of the technology nest

$\alpha \in ALEO(\subset A)$ activities with a Leontief function at the top of the technology nest

$c \in C$ commodities

$c \in CD(\subset C)$	commodities with domestic sales of domestic output
$c \in CDN(\subset C)$	commodities not in CD
$c \in CE(\subset C)$	exported commodities
$c \in CEN(\subset C)$	commodities not in CE
$c \in CM(\subset C)$	imported commodities
$c \in CMN(\subset C)$	commodities not in CM
$c \in CT(\subset C)$	transactions service commodities
$c \in CX(\subset C)$	commodities with domestic production
$f \in F$	factors
$i \in INST$	institutions (domestic and rest of the world)
$i \in INSD(\subset INS)$	domestic institutions
$i \in INSDNG(\subset INSD)$	domestic non-government institutions
$h \in H(\subset INSDNG)$	households

PARAMETERS

Latin Letters

$cwts_c$ weight of commodity *c* in the *CPI*

$dwts_c$ weight of commodity *c* in the producer price index

$ica_{c\,a}$ quantity of *c* as intermediate input per unit of activity *a*

$icd_{c\,c'}$ quantity of commodity *c* as trade input per unit of *c'* produced and sold domestically

$ice_{c\,c'}$ quantity of commodity *c* as trade input per exported unit of *c'*

$icm_{c\,c'}$ quantity of commodity *c* as trade input per imported unit of *c'*

$inta_a$ quantity of aggregate intermediate input per activity unit

iva_a quantity of value-added per activity unit

$\overline{mps_\iota}$ base savings rate for domestic institutions *i*

$mps01_c$ 0-1 parameter with 1 for institutions with potentially flexed direct tax rates

pwe_c export price (foreign currency)

pwm_c import price (foreign currency)

$qdstokconst_c$ quantity of stock change

$\overline{qg}_c$ base-year quantity of government demand

$\overline{q\iota nv}_c$ base-year quantity of private investment demand

$shif_{i\,f}$ share for domestic institution *i* in income of factor *f*

$shii_{i\,i'}$ share of net income of *i'* to $(i' \in INSDNG'; i \in INSDNG$

$t\alpha_\alpha$ tax rate for activity *a*

te_c export tax rate

tf_f direct tax rate for factor *f*

$\overline{tins}_i$ exogenous direct tax rate for domestic institution *i*

$tins01_i$ 0-1 parameter with 1 for institutions with potentially flexed direct tax rates

tm_c import tariff rate

tq_c rate of sales tax

$trnsfr_{i\,f}$ transfer from factor *f* to institution *i*

tva_a rate of value-added tax for activity *a*

Greek Letters

α_a^a efficiency parameter in the CES activity function

α_a^{va} efficiency parameter in the CES value-added function

α_a^{ac} shift parameter for domestic commodity aggregation function

α_c^q Armington function shift parameter

α_c^t CET function shift parameter

$\beta_{a\,c\,h}^h$ marginal share of consumption spending on home commodity c from activity a for household h

$\beta_{c\,h}^m$ marginal share of consumption spending on marketed commodity c for household h

δ_a^a CES activity function share parameter

$\delta_{a\,c}^{ac}$ share parameter for domestic commodity aggregation function

δ_c^q Armington function share parameter

δ_c^t CET function share parameter

$\delta_{f\,a}^{va}$ CES value-added function share parameter for factor f in activity a

$\gamma_{c\,h}^m$ subsistence consumption of marketed commodity c for household h

$\gamma_{a\,c\,h}^h$ subsistence consumption of home commodity c from activity a for household h

$\theta_{a\,c}$ yield of output c per unit of activity a

ρ_a^a CES production function exponent

ρ_a^{va} CES value-added function exponent

ρ_c^{ac} domestic commodity aggregation function exponent

ρ_c^q Armington function exponent

ρ_c^t CET function exponent

EXOGENOUS VARIABLES

$\overline{CPI}$ consumer price index

$\overline{DTINS}$ change in domestic institution tax share (= 0 for base; exogenous variable)

$\overline{FSAV}$ foreign savings (FCU)

$\overline{GOVTADJ}$ government consumption adjustment factor

$\overline{INVESTADJ}$ investment adjustment factor

$\overline{MPSADJ}$ savings rate scaling factor (= 0 for base)

$\overline{QFACTS_f}$ quantity supplied of factor

$\overline{TINSADJ}$ direct tax scaling factor (= 0 for base; exogenous variable)

$\overline{WFACTDIST_{fa}}$ wage distortion factor for factor f in activity a

ENDOGENOUS VARIABLES

$DMPS$ change in domestic institution savings rates (= 0 for base; exogenous variable)

DPI producer price index for domestically marketed output

EG government expenditures

EH_h consumption spending for household

EXR exchange rate (*LCU* per unit of *FCU*)

$GOVSHR$ government consumption share in nominal absorption

$GSAV$ government savings

$INVSHR$ investment share in nominal absorption

MPS_i marginal propensity to save for domestic nongovernment institution (exogenous variable)

PA_a activity price (unit gross revenue)

PDD_c demand price for commodity produced and sold domestically

PDS_c supply price for commodity produced and sold domestically

PE_c export price (domestic currency)

$PINTA_c$ aggregate intermediate input price for activity *a*

PM_c import price (domestic currency)

PQ_c composite commodity price

PVA_a value-added price (factor income per unit of activity)

PX_c aggregate producer price for commodity

$PXAC_c$ producer price of commodity *c* for activity *a*

QA_a quantity (level) of activity

QD_c quantity sold domestically of domestic output

QE_c quantity of exports

$QF_{f\ a}$ quantity demanded of factor *f* from activity *a*

QG_c government consumption demand for commodity

$QH_{c\ h}$ quantity consumed of commodity *c* by household *h*

$QHA_{a\ c\ h}$ quantity of household home consumption of commodity *c* from activity a for household *h*

$QINTA_a$ quantity of aggregate intermediate input

$QINT_{c\,a}$ quantity of commodity *c* as intermediate input to activity *a*

$QINV_c$ quantity of investment demand for commodity

QM_c quantity of imports of commodity

QQ_c quantity of goods supplied to domestic market (composite supply)

QT_c quantity of commodity demanded as trade input

QVA_a quantity of (aggregate) value-added

QX_c aggregated marketed quantity of domestic output of commodity

$QXAC_{a\,c}$ quantity of marketed output of commodity *c* from activity *a*

$TABS$ total nominal absorption

$TINS_i$ direct tax rate for institution *i* ($i \in$ INSDNG)

$TRII_{i\,i'}$ transfers from institution *i*' to *i* (both in the set INSDNG)

WF_f average price of factor *f*

YF_f income of factor *f*

YG government revenue

YI_i income of domestic nongovernment institution

$YIF_{i\,f}$ income to domestic institution *i* from factor *f*

For easy descriptions, the model block equations are grouped under their headings; price block equations, production and trade block equations, institutions block equations, and system constraints block equations.

Price Block Equations

The price block equations describe how the prices in the model are determined. Lofgren *et al.*, (2002) articulates that the price system of the model is rich, primarily because of the assumed quality differences among commodities of different origins and destinations (exports, imports, and domestic outputs used domestically). The price block is composed of equations linking the endogenous model prices to other prices (either also endogenous or exogenous) and to non-price model variables.

1. **Import Price**

$$PM_c = pwm_c * (1 + tmc_c) * EXR + \sum_{c' \epsilon CT} PQ_{c'} + icm_{c'c}$$

$$\begin{bmatrix} import \\ price \\ (LCU) \end{bmatrix} = \begin{bmatrix} import \\ price \\ (FCU) \end{bmatrix} * \begin{bmatrix} tariff \\ adjustment \end{bmatrix} * \begin{bmatrix} exchange\ rate \\ (LCU\ per \\ FCU) \end{bmatrix} + \begin{bmatrix} cost\ of\ trade \\ inputs\ per \\ import\ unit \end{bmatrix} \quad c \in CM$$

2. **Export Price**

$$PE_c = pwe_c * (1 - te_c) * EXR - \sum_{c' \in CT} PQ_{c'} * ice_{c'c}$$

$$\begin{bmatrix} export \\ price \\ (LCU) \end{bmatrix} = \begin{bmatrix} export \\ price \\ (FCU) \end{bmatrix} * \begin{bmatrix} tariff \\ adjustment \end{bmatrix} * \begin{bmatrix} exchange\ rate \\ (LCU\ per \\ FCU) \end{bmatrix} + \begin{bmatrix} cost\ of\ trade \\ inputs\ per \\ export\ unit \end{bmatrix} \quad c \in CE$$

3. **Demand Price of Domestic Non-Traded Goods**

$$PDD_c = PDS_c + \sum_{c' \in CT} PQ_{c'} . icd_{c'c}$$

$$\begin{bmatrix} domestic \\ demand \\ price \end{bmatrix} = \begin{bmatrix} domestic \\ supply \\ price \end{bmatrix} + \begin{bmatrix} cost\ of\ trade \\ inputs\ per \\ unit\ of \\ domestic\ sales \end{bmatrix} \qquad c \in CD$$

4. **Absorption**

$$PQ_c.(1 - tq_c).QQ_c = PDD_c.QD_c + PM_c.QM_c$$

$$\begin{bmatrix} absorption \\ (at\ demand \\ prices\ net\ of \\ sales\ tax) \end{bmatrix} = \begin{bmatrix} domestic\ domestic\ price \\ times \\ domestic\ sales\ quantity \end{bmatrix} + \begin{bmatrix} import\ price \\ times \\ import\ quantity \end{bmatrix} \qquad c \in (CD \cup CM)$$

5. **Marketed Output Value**

$$PX_c.QX_c = PDS_c.QD_c + PE_c.QE_c$$

$$\begin{bmatrix} producer\ price \\ times\ marketed \\ output\ quantity \end{bmatrix} = \begin{bmatrix} domestic\ supply\ price \\ times \\ domestic\ sales\ quantity \end{bmatrix} + \begin{bmatrix} export\ price \\ times \\ export\ quantity \end{bmatrix} \qquad c \in CX$$

6. **Activity Price**

$$PA_c = \sum_{c \in C} PXAC_{a\,c}\,.\theta_{a\,c}$$

$$\begin{bmatrix} activity \\ price \end{bmatrix} = \begin{bmatrix} producer\ price \\ times \\ yields \end{bmatrix} \qquad a \in A$$

7. **Aggregate Intermediate Input Price**

$$PINTA_a = \sum_{c \in C} PQ_c\,.ica_{c\,a}$$

$$\begin{bmatrix} aggregate \\ intermediate \\ input\ price \end{bmatrix} = \begin{bmatrix} intermediate\ input\ cost \\ per\ unit\ of\ aggregate \\ intermediate\ input \end{bmatrix} \qquad a \in A$$

8. Activity Revenue and Costs

$$PA_a.(1 - ta_a).QA_a = PVA_a.QVA_a + PINTA_a.QINTA_a$$

$$\begin{bmatrix} activity\ price \\ (net\ of\ taxes) \\ times\ activity\ level \end{bmatrix} = \begin{bmatrix} value - added \\ price\ times \\ quantity \end{bmatrix} + \begin{bmatrix} aggregate\ intermediate \\ input\ price\ times \\ quantity \end{bmatrix} \qquad a \in A$$

9. Consumer Price Index

$$\overline{CPI} = \sum_{c \in C} PQ_c\,.cwts_c$$

$$\begin{bmatrix} consumer \\ price \\ index \end{bmatrix} = \begin{bmatrix} prices \\ times \\ weights \end{bmatrix}$$

10. Producer Price Index for Nontraded Market Output

$$DPI = \sum_{c \in C} PDS_c\,.dwts_c$$

$$\begin{bmatrix} producer\ price\ index \\ for \\ non - traded\ outputs \end{bmatrix} = \begin{bmatrix} prices \\ times \\ weights \end{bmatrix}$$

PRODUCTION AND TRADE BLOCK

11. CES Technology: Activity Production Function

$$QA_{\boldsymbol{a}} = \alpha_a^a . (\delta_a^a . QVA_a^{-\rho_a^a} + (1 - \delta_a^a) . QINTA_a^{-\rho_a^a})^{-\frac{1}{\rho_a^a}}$$

$$\begin{bmatrix} activity \\ level \end{bmatrix} = CES \begin{bmatrix} quantity\ of\ aggregate\ value\ added, \\ quantity\ of\ aggregate\ intermediate\ input \end{bmatrix} \qquad a \in ACES$$

12. ACES Technology: Value-Added-Intermediate-Input Ratio

$$\frac{QVA_a}{QINTA_a} = (\frac{PINTA_a}{PVA_a} . \frac{\delta_a^a}{1 - \delta_a^a})^{\frac{1}{1+\rho_a^a}}$$

$$\begin{bmatrix} value - added \\ intermediate\ input \\ quantity\ ratio \end{bmatrix} = f \begin{bmatrix} intermediate - input: \\ value - added \\ price\ ratio \end{bmatrix} \qquad a \in ACES$$

13. Leontief Technology: Demand for Aggregate Value-Added

$$QVA_a = iva_a . QA_a$$

$$\begin{bmatrix} demand\ for \\ value\ added \end{bmatrix} = f \begin{bmatrix} activity \\ level \end{bmatrix} \qquad a \in ALEO$$

14. Leontief Technology: Demand for Aggregate Intermediate Input

$$QINTA_a = inta_a . QA_a$$

$$\begin{bmatrix} demand\ for\ aggregate \\ intermediate \end{bmatrix} = f \begin{bmatrix} activity \\ level \end{bmatrix} \qquad a \in ALEO$$

15. Value-Added and Factor Demands

$$QVA_a = \alpha_a^{va}.(\sum_{f \in F} \delta_{f\,a}^{va}.QF_{f\,a}^{-\rho_a^{va}})^{-\frac{1}{\rho_a^{va}}}$$

$$\begin{bmatrix} quantity\ of\ aggregate \\ value\ added \end{bmatrix} = CES \begin{bmatrix} factor \\ inputs \end{bmatrix} \qquad a \in A$$

16. Factor Demands

$$WF_f.\overline{WFDIST_{f\,a}} = PVA_a(1 - tva_a).QVA_a.(\sum_{f \in F} \delta_{f\,a}^{va}.QF_{f\,a}^{-\rho_a^{va}})^{-1}.\delta_{f\,a}^{va}.QF_{f\,a}^{-\rho_a^{va}-1}$$

$$\begin{bmatrix} marginal\ cost\ of \\ factor\ f\ in\ activity\ a \end{bmatrix} = \begin{bmatrix} marginal\ revenue\ product \\ of\ factor\ f\ in\ activity\ a \end{bmatrix} \qquad a \in A,\ f \in F$$

17. Disaggregated Intermediate Input Demand

$$QINTA_{c\,a} = ica_{c\,a}.QINTA_a$$

$$\begin{bmatrix} intermediate\ demand \\ for\ commodity\ c \\ from\ activity\ a \end{bmatrix} = f \begin{bmatrix} aggregate\ intermediate \\ input\ quantity \\ for\ activity\ a \end{bmatrix} \qquad a \in A,\ c \in C$$

18. Commodity Production and Allocation

$$QXAC_{a\,c} + \sum_{h \in H} QHA_{a\,c\,h} = \theta_{a\,c} \, . \, QA_a$$

$$\begin{bmatrix} marketed\ quantity \\ of\ commodity\ c \\ from\ activity\ a \end{bmatrix} + \begin{bmatrix} household\ home \\ consumption \\ of\ commodity\ c \\ from\ activity\ a \end{bmatrix} = \begin{bmatrix} production \\ of\ commodity\ c \\ from\ activity\ a \end{bmatrix} \quad a \in A,\ c \in CX$$

19. Output Aggregation Function

$$QX_c = \alpha_c^{ac} . (\sum_{a \in A} \delta_{a\,c}^{ac} \, . \, QXAC_{a\,c}^{-\rho_c^{ac}})^{-\frac{1}{\rho_c^{ac}-1}}$$

$$\begin{bmatrix} aggregate\ marketed \\ production\ of \\ commodity\ c \end{bmatrix} = CES \begin{bmatrix} activity - specific \\ marketed\ production \\ of\ commodity\ c \end{bmatrix} \qquad c \in CX$$

20. First-Order Condition for Output Aggregation Function

$$PXAC_{a\ c} = PX_c . QX_c (\sum_{a \in A} \delta_{a\,c}^{ac} \, . \, QXAC_{a\,c}^{-\rho_c^{ac}})^{-1} . \delta_{a\,c}^{ac} . QXAC_{a\ c}^{-\rho_a^{ac}-1}$$

$$\begin{bmatrix} marginal\ cost\ of \\ commodity\ c \\ from\ activity\ a \end{bmatrix} = \begin{bmatrix} marginal\ revenue\ product\ of \\ commodity\ c\ from\ activity\ a \end{bmatrix} \qquad a \in A,\ c \in CX$$

21. Output Transformation (CET) Function

$$QX_c = \alpha_c^t . (\delta_c^t . QE_c^{\rho_c^t} + (1 - \delta_c^t) . QD_c^{\rho_c^t})^{\frac{1}{\rho_c^t}}$$

$$\begin{bmatrix} aggregate\ marketed \\ domestic\ output \end{bmatrix} = CET \begin{bmatrix} export\ quantity, domestic \\ sales\ of\ domestic\ output \end{bmatrix} \qquad c \in (CE \cap CD)$$

22. Export-Domestic Supply Ratio

$$\frac{QE_c}{QD_c} = (\frac{PE_c}{PDS_c} . \frac{1-\delta_c^t}{\delta_c^t})^{\frac{1}{\rho_c^t - 1}}$$

$$\begin{bmatrix} export - \\ domestic \\ supply\ ratio \end{bmatrix} = f \begin{bmatrix} export - domestic \\ price\ ratio \end{bmatrix} \qquad c \in (CE \cap CD)$$

23. Output Transformation for Domestically Sold Outputs Without Exports and for Exports Without Domestic Sales

$$QX_c = QD_c + QE_c$$

$$\begin{bmatrix} aggregate \\ marketed \\ domestic \\ output \end{bmatrix} = \begin{bmatrix} domestic \\ market \\ sales\ of \\ domestic \\ output \\ [for \\ c \in (CD \cap CEN)] \end{bmatrix} + \begin{bmatrix} exports\ [for \\ c \in (CE \cap CDN)] \end{bmatrix} \quad c \in (CD \cap CEN) \cup (CE \cap CDN)$$

24. Composite Supply (Armington) Function

$$QQ_c = \alpha_c^q . (\delta_c^q . QM_c^{-\rho_c^q} + \left(1 - \delta_c^q\right) . QD_c^{-\rho_c^q})^{-\frac{1}{\rho_c^q}}$$

$$\begin{bmatrix} composite \\ supply \end{bmatrix} = f \begin{bmatrix} import\ quantity, domestic \\ use\ of\ domestic\ output \end{bmatrix} \qquad c \in (CM \cap CD)$$

25. Import-Domestic Demand Ratio

$$\frac{QM_c}{QD_c} = \left(\frac{PDD_c}{PM_c} . \frac{\delta_c^q}{1-\delta_c^q}\right)^{\frac{1}{1+\rho_c^q}}$$

$$\begin{bmatrix} import - domestic \\ demand\ ratio \end{bmatrix} = f \begin{bmatrix} domestic - import \\ price\ ratio \end{bmatrix} \qquad c \in (CM \cap CD)$$

26. Composite Supply for Non-Imported Outputs and Non-produced Imports

$$QQ_c = QD_c + QM_c$$

$$\begin{bmatrix} composite \\ supply \end{bmatrix} = \begin{bmatrix} domestic \\ use\ of \\ marketed \\ domestic \\ output\ [for \\ c \in (CD \cap CMN)] \end{bmatrix} + \begin{bmatrix} imports \\ [for \\ c \in (CM \cap CDN)] \end{bmatrix} \quad c \in (CD \cap CMN)) \cup (CM \cap CDN)$$

27. Demand for Transactions Services

$$QT_c = \sum_{c\prime \in C\prime} (icm_{c\,c\prime} . QM_{c\prime} + ice_{c\,c\prime} . QE_{c\prime} + icd_{c\,c\prime} . QD_{c\prime})$$

$$\begin{bmatrix} demand\ for \\ transaction \\ services \end{bmatrix} = \begin{bmatrix} sum\ of\ demands \\ for\ imports, exports \\ and\ domestic\ sales \end{bmatrix} \qquad c \in CT$$

INSTITUTION BLOCK

28. Factor Income

$$YF_f = \sum_{a \in A} WF_f . \overline{WFDIST_{f\ a}} . QF_{f\ a}$$

$$\begin{bmatrix} income\ of \\ factor\ f \end{bmatrix} = \begin{bmatrix} sum\ of\ activity\ payments \\ (activity - specific\ wages \\ times\ employment\ levels \end{bmatrix} \qquad f \in F$$

29. Institutional Factor Incomes

$$YIF_{i\ f} = shif_{i\ f}.\left[\left(1 - tf_f\right).YF_f - trnsfr_{row\ f}.EXR\right]$$

$$\begin{bmatrix} income\ of \\ institution\ i \\ from\ factor\ f \end{bmatrix} = \begin{bmatrix} share\ of\ income \\ of\ factor\ f \\ to\ institution\ i \end{bmatrix} . \begin{bmatrix} income\ of\ factor\ f \\ (net\ of\ tax\ and \\ transfer\ to\ RoW \end{bmatrix} \qquad i \in INSD, f \in F$$

30. Income of Domestic, Nongovernment Institutions

$$YI_i = \sum_{f \in F} YIF_{i\ f} + \sum_{i' \in INSDNG'} TRII_{i\ i'} + trnsfr_{i\ gov}.\overline{CPI} + trnsfr_{i\ row}.EXR$$

$$\begin{bmatrix} income\ of \\ institution\ i \end{bmatrix} = \begin{bmatrix} factor \\ income \end{bmatrix} + \begin{bmatrix} transfers \\ from\ other\ domestic \\ non - government \\ institutions \end{bmatrix} + \begin{bmatrix} transfers \\ from \\ government \end{bmatrix} + \begin{bmatrix} transfers \\ from \\ RoW \end{bmatrix} \qquad i \in INSDNG$$

31. Infra-Institutional Transfers

$$TRII_{i\ i'} = shii_{i\ i'}.\left(1 - MPS_{i'}\right).\left(1 - TINS_{i'}\right).YI_{i'}$$

$$\begin{bmatrix} transfer\ from \\ institution\ i'\ to\ i \end{bmatrix} = \begin{bmatrix} share\ of \\ net\ income \\ of\ institution\ i' \\ transfered\ to\ i \end{bmatrix} * \begin{bmatrix} income\ of \\ institution\ i', \\ net\ of\ savings \\ and\ direct\ taxes \end{bmatrix} i \in INSDNG, i' \in INSDNG'$$

32. Household Consumption Expenditure

$$EH_h = \left(1 - \sum_{i \in INSDNG} shii_{i\,h}\right).(1 - MPS_h).(1 - TINS_h).YI_h$$

$$\begin{bmatrix} household\ income \\ disposable\ for \\ consumption \end{bmatrix} = \begin{bmatrix} household\ income, net\ of\ direct \\ taxes, savings, and\ transfers\ to \\ other\ non-governmental\ institutions \end{bmatrix} \qquad h \in H$$

33. Household Consumption Spending on Marketed Commodities

$$PQ_c.QH_{c\,h} = PQ_c.\gamma^m_{c\,h} + \beta^m_{c\,h}.(EH_h - \sum_{c' \epsilon C} PQ_{c'}.\gamma^m_{c'h} - \sum_{a \epsilon A}\sum_{c' \epsilon C} PXAC_{a\,c'}.\gamma^h_{a\,c'h})$$

$$\begin{bmatrix} household\ consumption \\ spending\ on\ market \\ commodity\ c \end{bmatrix} = f\begin{bmatrix} total\ household\ consumption \\ spending, market\ prices\ of\ c, and\ other \\ commodity\ prices(market\ and\ home) \end{bmatrix} \qquad c \in C,\ \ h \in H$$

34. Household Consumption Spending on Home Commodities

$$PXAC_{a\,c}.QHA_{a\,c\,h} = PXAC_{a\,c}.\gamma^h_{a\,c\,h} + \beta^h_{a\,c\,h}.(EH_h - \sum_{c' \epsilon C} PQ_c.\gamma^m_{c'h} - \sum_{a \epsilon A}\sum_{c \epsilon C} PXAC_{a\,c}.\gamma^h_{a\,c'h})$$

$$\begin{bmatrix} household\ consumption \\ spending\ on\ home\ commodity \\ c\ from\ activity\ a \end{bmatrix} = f\begin{bmatrix} total\ household\ consumption\ spending, \\ producer\ price, and\ other \\ commodity\ prices\ (market\ and\ home) \end{bmatrix} \qquad a \in A, c \in C,\ \ h \in H$$

35. Investment Demand

$$QINV_c = \overline{IADJ}.\overline{qinv_c}$$

$$\begin{bmatrix} fixed\ investment \\ demand\ for \\ commodity\ c \end{bmatrix} = \begin{bmatrix} adjustment\ factor \\ times \\ base-year\ fixed \\ investment \end{bmatrix} \qquad c \in C$$

36. Government Consumption Demand

$$QG_c = \overline{GADJ}.\overline{qg_c}$$

$$\begin{bmatrix} government \\ consumption \\ demand\ for \\ commodity\ c \end{bmatrix} = \begin{bmatrix} adjustment\ factor \\ times \\ base-year\ government \\ consumption \end{bmatrix} \qquad c \in C$$

37. Government Revenue

$$YG = \sum_{i \in INSDNG} TINS_i.YI_i + \sum_{f \in F} tf_f.YF_f + \sum_{a \in A} tva_a.PVA_a.QVA_a + \sum_{a \in A} ta_a.PA_a.QA_a + \sum_{c \in CM} tm_c.pwm_c.QM_c.EXR + \sum_{c \in CE} te_c.pwe_c.QE_c.EXR + \sum_{c \in C} tq_c.PQ_c.QQ_c + \sum_{f \in F} YIF_{gov\ f}.trnsfr_{gov\ row}.EXR$$

$$\begin{bmatrix} government \\ revenue \end{bmatrix} = \begin{bmatrix} direct\ taxes \\ from \\ institutions \end{bmatrix} + \begin{bmatrix} direct\ taxes \\ from \\ factors \end{bmatrix} + \begin{bmatrix} value- \\ added \\ tax \end{bmatrix} + \begin{bmatrix} activity \\ tax \end{bmatrix} + \begin{bmatrix} import \\ tariffs \end{bmatrix} + \begin{bmatrix} export \\ taxes \end{bmatrix} + \begin{bmatrix} sales \\ taxes \end{bmatrix} + \begin{bmatrix} factor \\ income \end{bmatrix} + \begin{bmatrix} transfers \\ from \\ RoW \end{bmatrix}$$

38. Government Expenditure

$$EG = \sum_{c \in C} PQ_c . QG_c + \sum_{i \in INSDNG} trnsfr_{i\ gov} . \overline{CPI}$$

$$\begin{bmatrix} government \\ spending \end{bmatrix} = \begin{bmatrix} government \\ consumption \end{bmatrix} + \begin{bmatrix} transfers\ to\ domestic \\ non-government \\ institutions \end{bmatrix}$$

SYSTEM CONSTRAINT BLOCK

39. Factor Markets

$$\sum_{a \in A} QF_{f\ a} = \overline{QFS_f}$$

$$\begin{bmatrix} demand\ for \\ factor\ f \end{bmatrix} = \begin{bmatrix} supply\ of \\ factor\ f \end{bmatrix} \qquad f \in F$$

40. Composite Commodity Markets

$$QQ_c = \sum_{a \in A} QINT_{c\ a} + \sum_{h \in H} QH_{c\ h} + QG_c + QINV_c + qdst_c + QT_c$$

$$\begin{bmatrix} composite \\ supply \end{bmatrix} = \begin{bmatrix} intermediate \\ use \end{bmatrix} + \begin{bmatrix} household \\ consumption \end{bmatrix} + \begin{bmatrix} government \\ consumption \end{bmatrix} + \begin{bmatrix} fixed \\ investment \end{bmatrix} + \begin{bmatrix} stock \\ change \end{bmatrix} + \begin{bmatrix} trade \\ input\ use \end{bmatrix} \qquad c \in C$$

41. Current-Account Balance for the Rest of the World, in Foreign Currency

$$\sum_{c\in CM} pwm_c . QM_c + \sum_{f\in F} trnsfr_{row\,f} = \sum_{c\in CE} pwe_c . QE_c + \sum_{i\in INSDNG} trnsfr_{i\,row} + \overline{FSAV}$$

$$\begin{bmatrix} import \\ spending \end{bmatrix} + \begin{bmatrix} factor \\ transfers \\ to\ RoW \end{bmatrix} = \begin{bmatrix} export \\ revenue \end{bmatrix} + \begin{bmatrix} institutional \\ transfers \\ from\ RoW \end{bmatrix} + \begin{bmatrix} foreign \\ savings \end{bmatrix}$$

42. Government Balance

$$YG = EG + GSAV$$

$$\begin{bmatrix} government \\ revenue \end{bmatrix} = \begin{bmatrix} government \\ expenditures \end{bmatrix} + \begin{bmatrix} government \\ savings \end{bmatrix}$$

43. Direct Institutional Tax Rates

$$TIINS_t = \overline{tins_i} . (1 + \overline{TINSADJ} . tins01_i) + \overline{DTINS} . t$$

$$\begin{bmatrix} direct \\ rate\ for \\ institutions \end{bmatrix} = \begin{bmatrix} base\ rate\ adjustment \\ for\ scaling\ for \\ selected\ institutions \end{bmatrix} + \begin{bmatrix} point\ change \\ for\ selected \\ institutions \end{bmatrix} \qquad i \in INSDNG$$

44. Institutional Savings Rates

$$MPS_i = \overline{mps_i}.(1 + \overline{MPSADJ}.mps01_i) + DMPS.mps01_i$$

$$\begin{bmatrix} savings \\ rate\ for \\ institution\ i \end{bmatrix} = \begin{bmatrix} base\ rate\ adjusted \\ for\ scaling\ for \\ selected\ institutions \end{bmatrix} + \begin{bmatrix} point\ change \\ for\ selected \\ institutions \end{bmatrix} \qquad i \in INSDNG$$

45. Savings-Investment Balance

$$\sum_{i \epsilon INSDNG} MPS_i.(1 - TINS_i).YI_i + GSAV + EXR.\overline{FSAV} = \sum_{c \epsilon C} PQ_c.QINV_c + \sum_{c \epsilon C} PQ_c.qdst_c$$

$$\begin{bmatrix} non - government \\ savings \end{bmatrix} + \begin{bmatrix} government \\ savings \end{bmatrix} + \begin{bmatrix} foreign \\ savings \end{bmatrix} = \begin{bmatrix} fixed \\ investment \end{bmatrix} + \begin{bmatrix} stock \\ change \end{bmatrix}$$

46. Total Absorption

$$TABS = \sum_{h \epsilon H} \sum_{c \epsilon C} PQ_c.QH_{c\,h} + \sum_{a \epsilon A} \sum_{c \epsilon C} \sum_{h \epsilon H} PXAC_{a\,c}.QHA_{a\,c\,h} + \sum_{c \epsilon C} PQ_c.QG_c + \sum_{c \epsilon C} PQ_c.QINV_c + \sum_{c \epsilon C} PQ_c.qdst_c$$

$$\begin{bmatrix} total \\ absorption \end{bmatrix} = \begin{bmatrix} household \\ market \\ consumption \end{bmatrix} + \begin{bmatrix} household \\ home \\ consumption \end{bmatrix} + \begin{bmatrix} government \\ consumption \end{bmatrix} + \begin{bmatrix} fixed \\ investmet \end{bmatrix} + \begin{bmatrix} stock \\ change \end{bmatrix}$$

47. Ratio of Investment to Absorption

$$INVSHR.TABS = \sum_{c \in C} PQ_c . QINV_c + \sum_{c \in C} PQ_c . qdst_c$$

$$\begin{bmatrix} investment \\ absorption \\ ratio \end{bmatrix} . \begin{bmatrix} total \\ absorption \end{bmatrix} = \begin{bmatrix} fixed \\ investment \end{bmatrix} + \begin{bmatrix} stock \\ change \end{bmatrix}$$

48. Ratio of Government Consumption to Absorption

$$GOVSHR.TABS = \sum_{c \in C} PQ_c . QG_c$$

$$\begin{bmatrix} government \\ consumption \\ absorption\ ratio \end{bmatrix} . \begin{bmatrix} total \\ absorption \end{bmatrix} = \begin{bmatrix} government \\ consumption \end{bmatrix}$$

Appendix C2

INCORPORATION OF THE DYNAMIC UPDATING EQUATIONS

The specifications of the updating equations for factor supplies, factor productivity and population growth are presented below.

4.3.1 Capital Accumulation

The updating of the capital accumulation process involves four steps; (i) first the average economy-wide rental rate of capital (AWF_{ft}^{a}) is calculated for time period *t*. It is given by the sum of the rental rates of each sector weighted by the sector's share of total capital factor demand, i.e

$$AWF_{f,t}^{a} = \sum_{a}\left[\left(\frac{QF_{f,a,t}}{\sum_{a} QF_{f,a,t}}\right) * WF_{f,t} * WFDIST_{f,a,t}\right]$$

(ii) Secondly, each sector's new capital or investment share is adjusted. It is computed by the ratio of the sector's profit rate to the average profit rate for the entire economy, i.e.,

$$\eta_{f,a,t}^{a} = \left(\frac{QF_{f,a,t}}{\sum_{a} QF_{f,a,t}}\right) * \left[\beta^{a} * \left(\frac{WF_{f,t} * WFDIST_{f,a,t}}{AWF_{f,t}^{a}} - 1\right) + 1\right]$$

Where (η_{fat}^{a}) is the adjusted share of sector a in the new capital and the term β^{a} is the inter-sectoral mobility of investment. In the extreme case β^{a} assumes the value of zero indicating that there is no inter-sectoral mobility of investment funds and all investment can be thought of as being funded by retained profits- thus ignoring savings from government and labour income (Thurlow, 2004). However, it must be noted that this *beta* “is not an index of the degree of perfection of capital markets. Even if is zero, the system may move toward equalizing profit rates over time, and, if is too large, it is easy to make sectoral profit rates oscillate. For the latter specifications, by contrast, the sectors which have higher (lower) profitability than the average profitability in current period will get higher (lower) shares of the available investment, (Tlhalefang, 2019). It is therefore expected that the sectors with higher (lower) profitability should experience a faster (slower) increases in their capital stock and production than for other sectors hence a decline in their relative prices and so should their profit rates. Consequently, sectoral profits lower or higher than average profits will in the long run be eliminated through competitive investment in a competitive market hence sectoral investment shares in later years, and as a result sectoral growth rates, change due to differences in sectoral profit rates. This β^{a} parameter as succinctly described by Dervis *et al*., (1982), is rather an indicator of the responsiveness of capital markets to static signals, namely, current profit rates in the various sectors.”

Third, there is an updating equation for the quantity of new capital is distributed to destination sectors in proportion to sectors’ adjusted share in aggregate capital. This is computed as the value of gross fixed capital formation divided by the unit price of capital(PK_{ft}) which is determined as the weighted market price of investment commodities, where the weights are shares of investment goods in total investment, thus,

$$PK_{f,t} = \sum_a PQ_{c,t} * \frac{QINV_{c,t}}{\sum_c QINV_{c,t}}$$

It is then multiplied by each sector's new capital investment share (η^a_{fat}) to get the final quantity allocated to each sector (ΔK^a_{fat}), i.e,

$$\Delta K^a_{f,a,t} = \eta^a_{f,a,t} * \sum_a \left[\frac{PQ_c * QINV_{c,t}}{PK_{f,t}} \right]$$

Finally, the new aggregate capital quantity or total capital stock (at the beginning of period *t+1* is given by the previous period's capital stock (QFS^f_{t+1}) minus depreciation (υ_f) plus the new capital;

$$QFS_{f,t+1} = QFS_{f,t} \left(1 + \frac{\sum_a \Delta K_{f,t}}{QFS_{f,t}} - v_f \right)$$

The sectoral capital quantities (QFS^f_{at+1}) are similarly adjusted from their previous levels to include new additions to the capital stock;

$$QF_{f,a,t+1} = QF_{f,a,t} \left(1 + \frac{\Delta K^a_{f,t}}{QF_{f,a,t}} - v_f \right)$$

4.3.2 Population Growth

The other variable that needs to be updated is population. The population growth equation transitions are updated as follows;

$$POP_{h,t} = POP_{h,t-1}(1+grpop)$$

4.3.3 Subsistence Consumption

For the household consumption spending on marketed commodities, away from the income-independent level of consumption terms, $(m, PQ_c.\gamma_{ch}^m)$ which is unaffected by changes in disposable income, measured as the market value of each household's consumption of each commodity, the level of additional consumption demand is determined by adjusting of the changes in income.

Subsistence consumption is therefore given by;

$$\gamma_{c,h,t} = \gamma_{c,h,t-1}(1+grc_h)$$

4.3.4 Labour Force Growth

In au fait that updating of the relevant parameters to reflect labour supply changes for this model depends on the labour market closure adopted for each labour category, a possible four factor market alternative closure options can be assumed; (i) labour supply can be assumed to be flexible but constrained in its ability to adjust by the real wage elasticity of labour supply. In this case, exogenous updating of labour supply QFS_f is unnecessary as labour supply is adjusted endogenously to determine final employment and wages. Should the labour supply for this factor grow exogenously then labour supply from its original level (QFS_f^0) from equation L which allows factor supply adjustment) is adjusted accordingly. For the second closure rule, labour category sectoral demand is fixed and any adjustments in demand following changes in labour supply are exogenous. Growth in supply is assumed to be the same across all sectors for this case. For the third closure option, labour is assumed to be unemployed at a fixed real wage- representing a special case for the first closure option in case where the wage elasticity of labour supply $etals_f$ is infinity. Analogous to the first closure option, the exogenous adjustment of labour supply QFS_f is unnecessary since there are no constraints on factor supply but rather exogenous adjustment of real wages is necessary. Finally, factor supply is assumed to be fixed while real wages are adjusted to equate demand and supply. This fourth closure option implies full employment. The fixed level of labour supply is adjusted exogenously between periods. This also represents a special case of the first closure where the wage elasticity of labour supply ($etals_f$) is zero.

For this model, it is assumed that unskilled labour is unemployed at a fixed real wage implies that there is no constraint on supply of unskilled labour. This obviates the need for exogenous adjustment of unskilled labour supply. Instead, the real wage for unskilled is exogenously adjusted. The supplies of skilled labour types, which are assumed to be fully employed within the period, are adjusted exogenously between the periods. These are assumed to grow at the rate of the population growth.

$$QFS_{f,t} = QFS_{f,t-1}(1 + grpop)$$

4.3.5 Total and Factor-Specific Productivity Growth

The dynamic module considers changes in factor productivity along with changes in factor supply. Factor productivity is calculated as;

$$TFP_{a,t} = TFP_{a,t-1}(1 + grtfp_a)$$

4.3.6 Government Consumption and Transfer Spending

With the fixed government consumption spending and transfers to households in real terms within a particular period, it is necessary to exogenously increase these payments between periods. In case of government consumption spending, the transition equation is updated as follows;

$$POP_{h,t} = POP_{h,t-1}\left(1 + grpop_h\right)$$

Appendix D1

Table 5.2: The Botswana Macro SAM

	Commodities	**Branches of activity**	**Factors of production**	**Households + NPISH**	**Corporations**	**Public administrations**	**Taxes minus subsidies**	**Capital - private**	**Capital - public**	**Changes in inventories**	**Rest of the World**	**TOTAL**
Commodities		99,412		48,629		19,407		26,436	7,204	6,856	48,463	**256,408**
Branches of activity	194,149											**194,149**
Factors of production		82,067										**82,067**
Households + NPISH			63,427			8,239						**71,666**
Corporations			736			-31						**704**
Public administrations			17,765	11,838	704	66	9,287				273	**39,934**
Taxes minus subsidies	9,836	-548										**9,287**
Capital - private		10,388		11,170		6,560					3,430	**31,548**
Capital - public		2,831				5,339					779	**8,949**
Changes in inventories								5,111	1,745			**6,856**
Rest of the World	52,423		139	29		355						**52,945**
TOTAL	**256,408**	**194,149**	**82,067**	**71,666**	**704**	**39,934**	**9,287**	**31,548**	**8,949**	**6,856**	**52,945**	

Appendix D2;
Table 5.2: Links Between Initial SAM and MODSAM2011 Accounts

	MODSAM2011 Accounts	Initial Botswana SAM
Commodities	Livestock	clivestock Livestock
	Other Agriculture	coagric Crops, Agriculture)
	Diamonds	cdiamonds Diamonds
	Copper	ccopper Copper
	Other Mining	comining Coal, Other Mining
	Petrol	cpetrol Petroleum
	Manufacturing	cmanuf Manufacturing
	Utilities	cutilities Water, Electricity
	Construction	cconstract Construction
	Wholesale	cwhole Wholesale, Retail
	Hotels & Restaurants	chotels Hotels
	Other Trade	cotrade Petrol, Vehicle Dealers, Other Trade
	Road Transport	croad Road
	Other Transport	cotranspo CTO, Railway, Air, Communications, Other Transports
	Business Services	cbusiness Banks, Insurance, Real Estate, Business Services, Own Occupied Dwellings
	Government	cgovt Central Government, Local Government
	Social Services	csocial Education, Health Services-Private, Health Services-Public, Personal Services, Domestic Services
Activities	Livestock	alivestock Livestock
	Other Agriculture	Aogric Crops, Other Agriculture
	Diamonds	adiamonds Diamonds
	Copper	acopper Copper,
	Other Mining	aomining Coal, Other Mining
	Manufacturing	amanuf Manufacturing
	Construction	aconstruc Construction
	Wholesale	awhole Wholesale, Retail
	Hotels & Restaurants	ahotels Hotels
	Other Trade	aotrade Petrol stations, Vehicle Dealers, Other Trade
	Road Transport	aroad Road
	Other Transport	aotrans CTO, Railway, Air, Communications, Other Transports
	Business Services	abusiness Banks, Insurance, Real Estate, Business, Electricity, Water, Own Occupied)
	Government	agovt Government
	Social Services	asocial NPISH, House Business, Domestic Services

Factors	Professional citizen labour Administration Managerial Clerical labour Skilled Manual citizen labour Unskilled citizen labour Mixed Income Gross Operating Surplus	Professional Adminman Clerical Skilmanual Unskilled Informal Grossurplus	Professional Admin managerial Clerical Skilmanual Unskilled Mixed Income Gross Surplus
Households	Cities Households Urban Households Rural Households	Hcities Hurban Hrural	Cities Households Urban Households Rural Households
Enterprises	Enterprises	Ent	Enterprises
Government	Government Tariff Collection Export Tax Collection Sales Taxes Direct income tax Activity collection tax	Gov Tar Etax Stax Ytax Atax	Government Tariff tax on Import Commodities Taxes on Export Commodities Taxes on Production Taxes on Income Value Added Tax
Capital Account	Savings-Investment Changes in Inventories	S-I dstk	Savings-Investment Changes in Inventories
Rest of World	Rest of the World	RoW	Rest of World

Appendix E1

5.1 Model Calibration

The Thurlow (2004) recursive dynamic CGE model is parameterized using the calibration method. The model distributive parameter values are, with behavioural parameter values econometrically estimated, retrieved from the SAM (benchmark data). The retrieved data from the SAM is checked if it is reproduced in the initial equilibrium values as depicted in the balanced SAM database. This also ascertains that the initial equilibrium values of certain variables are utilized for calibration and for initialization of computation. This non-stochastic or deterministic method is adopted, in part, because it is parsimonious, and also due to fact that it is extensively employed in virtually all CGE models and, in part, owing to the dearth of time-series data. The model was coded and solved in the GAMS modeling language.

The Thurlow recursive dynamic CGE model was parameterized and initialized to the modified Botswana economy 2011 SAM. This is done under the presupposition that the Botswana 2011 SAM database, for convenience and analytical consistency reasons, is a characterization of the Botswana economy in an initial inter-temporal equilibrium in 2011. Thus to say, the transactions portrayed in the 2011 SAM are considered as having been derived as part of a dynamic system which has achieved its inter-temporal equilibrium instead of the flow data being perceived as having been derived from the snapshot as in static CGE models. This interpretation facilitates the derivation of the adopted Thurlow model variables and distributive parameter values consistent with the observed data. Additionally, it establishes a direct and consistent relationship between the SAM database and the adopted dynamic CGE mode’s construction and analytical structure. After correctly calibrating the model’s parameters with policy instruments remaining at the levels observed in the SAM, the model solution is expected for each variable be exactly equal to its initial value as in the SAM.

With investment allocated by sectors' of destination, the trend equations, updating of government policy variables and other parameters, the model is run forward in time. This translates the single period model into a multi-period model. Initially, the parameterization procedure ensures that the dynamic mdel generates an equilibrium solution with values matching the benchmark data of the economy of Botswana.

The model is then run forward in GAMs/PATH using the dynamic data for exogenous variables and the updating of capital stock for twelve-year period. The Thulow model then solves for a series of sequence of equilibria for a eight-year period from 2011 to 2019 indicating how macro-economic indicators such as GDP, investment, private consumption, etc., and how the level and sectoral consumption, exports, imports, employment, investment, etc., envolved over the baseline scenario, spanning the eight-year time horizon, 2011-2019. This generates the BAU profile to which historical validation applies and also this part that is then subjected to counterfactual policy shocks (historical simulation). This process furnishes a baseline trajectory for growth and structural status of the Botswana economy with no productivity shock. After successfully calibrating the baseline scenario, the counterfactual simulations, increase in the livestock productivity, was then introduced. The model was then re-solved and the counterfactual equilibrium solution is analysed with reference to the base line. The variations are attributed to the simulated livestock productivity increase shock.

The model coding structure for the within-period module was derived from Lofgren *et al*., (2002) whilst for the between-period module is derived from Thurlow (2004).

Appendix E2

Table 5.3: Sectoral Value Added Annual Growth Rates

Sector	2011	2012	2013	2014	2015	2016	2017	2018	2019
livestock	-4.2	-11.3	-0.5	3.2	3.0	4.1	2.7	2.2	1.9
Other Agriculture	0.3	12.1	-5.0	-3.8	-0.4	1.6	2.5	2.5	2.5
Diamonds	5.7	-10.9	12.9	6.7	-15.6	0.3	9.9	6.2	4.2
Copper	-35.5	9.3	62.5	-15.5	-34.1	-21.2	-98.8	21.2	0
Other Mining	13.8	-6.5	15.6	9.2	-8.0	-1.0	-5.2	8.3	0
Manufacturing	11.4	3.7	6.5	0.5	3.2	1.6	2.2	3.6	3.2
Construction	23.1	14.4	4.1	3.7	4.0	4.2	3.5	3.7	3.9
Retail and Wholesale	-15.6	18.0	94.3	28.7	-48.7	74.1	25.9	-11.6	5.3
Hotels and Restaurants	15.9	4.9	6.7	5.7	5.9	5.2	5.6	7.2	6.4
Other Trade	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Road Transport	4.7	6.4	5.7	6.6	6.2	6.2	6.2	6.2	6.2
Other Transport	4.7	6.4	5.7	6.6	6.2	6.2	6.2	6.2	6.2
Business Services	7.7	9.1	8.7	2.7	4.5	3.3	4.1	5.0	3.8
Government Services	8.3	2.8	6.0	4.6	3.3	2.4	1.5	3.0	3.8
Social Services	8.3	10.7	8.0	4.2	3.6	3.5	2.8	3.6	3.6

Appendix F

Table 5.3: Annual growth rates of sectoral value added

	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Agriculture	2.5	2.7	2.3	2.1	2.2	2	2	2	1.9
Mining	23.4	17.6	19.4	22.2	17.8	20.5	17.4	16.5	15.2
Manufacturing	5.8	5.9	5.8	5.3	5.8	5.2	5.1	5.1	5.2
Water &Electricity	-0.1	-0.6	-0.1	-0.4	-0.2	0.2	1	1.2	1
Construction	6	6.8	6.4	6	6.6	6.2	6.4	6.6	6.8
Trade, Hotels&Restaurants	14.9	15.4	16.9	17.9	16.2	18.2	19.5	19.3	19.7
Transport &Communication	4.9	5.8	5.5	5.3	5.9	5.7	5.9	6	6.1
Finance &Business Service	13.3	15	14.2	13.2	14.7	13.7	13.9	14.1	14.5
General Government	14.1	15.4	14.2	13.7	15.4	14	14.3	14.5	14.7
Social & PersonalServices	5.6	6.1	5.9	5.6	5.9	5.4	5.5	5.5	5.6

Source: Statistics Botswana (2018)