Macroeconomic consequences of climate change: with a focus of the impacts on international trade flows for Ethiopia.

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DECLARATION

I, Hermela Wondwossen Lakew, hereby declare that this thesis work, entitled as: Macroeconomic consequences of climate change: with a focus of the impacts on international trade flows for Ethiopia; submitted in partial fulfilment of the requirements of the degree of Masters of Science in international Trade and Finance in the Faculty of Business and Economics, Department of Economics at Addis Ababa University, is my own independent work, and has not previously been submitted by me to any other university. I furthermore cede copyright of the thesis in favor of the Addis Ababa University.

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LIST OF ACRONYMS

ACPC	African Climate Policy Centre
AGCMs	Atmospheric General Circulation Models
CSAG	Climate System Analysis Group
CV	Coefficient of Variation
CGE	Computable General Equilibrium
CO_2	Carbon dioxide
CRGE	Climate Resilient Green Economy
FAO	Food and Agriculture Organization
GCMs	Global Climate Models/General Circulation Models
GDP	Gross Domestic Product
GHG	Green House Gases
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
PPP	Purchasing Power Parity
RCA	Revealed Comparative Advantage
THI	Temperature Humidity Index
UNFCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations International Children's Emergency Fund
USDA	United States Department of Agriculture
US	United States
WTO	World Trade Organization

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

This paper puts emphases on the analysis of international trade consequences of climate change in Ethiopia. It does so by first understanding impacts of climate damage on agricultural total factor productivity, hence, by estimating the indirect economic impacts resulting from changes in endowments and production. The study used a time series econometric analysis to determine the counterfactual impact of climate change on agricultural total productivity. Then the econometrics estimate was mapped to a dynamic computable general equilibrium model using the updated 2010 SAM data developed by EDRI. The modelling analysis presents a plausible scenario which is indicative of the international trade consequences of climate damages. The results estimated that with the inclusion of climate change, economic performance of the country declines relative to the baseline scenario where no climate damages exist. Exports contracts more than imports and GDP, mainly due to the larger impact climate change has on the main export goods of Ethiopia. Production costs increased resulting in an upward shift of produced goods which leads to an increase of product prices in the international market. The rise in the prices of goods in the international market will put an adverse pressure on Ethiopia's competitiveness. The important caveat to remember is that this study used one plausible scenario and baseline, hence, the results are more indicative of the impacts of climate change rather than firm predictions. The impact of climate change on chosen agricultural products are discussed in this paper, which will shed light on how Ethiopia's competitive advantage in the international market will be impacted. However, further studies are suggested which will input the economic consequences of climate change relative to competing countries. Thus, comparative advantage requires extensive data on the impact of climate change not only on the domestic economy but also the intensity of impacts on competing countries. It is suggested that international trade policy decisions should take into account the trade consequences of climate change. Hence, by being conscious of trade consequences of climate change, strong and aligned climate and trade policies can be design possibly avoiding the worst climate damages at least cost.

Key words: Climate change, International Trade, Comparative Advantage, Economic Growth, CGE model

CHAPTER 1: INTRODUCTION

1.1. BACKGROUND AND MOTIVATION

International trade is projected to outperform growth in global gross domestic product (GDP) over the next half century (Dellink et al., 2017). Economic growth has been evident in most African countries along with an increasing dependency of their economic performance on trade. However, climate change will affect trade patterns, specialization and domestic economic performance. Sub-Sharan African countries, particularly eastern African Countries continue to rely on trade of primary products which are highly vulnerable to climate change and extreme weather events. Climate impacts, such as those on agriculture and labor productivity, will cause changes in production and specialization, which will also affect trade (Dellink et al., 2017).

Food security is a major challenge faced by many African countries, specifically countries with a large number of households practicing small-scale farming in conventional agricultural systems. Among the many challenges that put pressure on countries striving to meet food security are increasing population sizes coupled with unstable climatic conditions (Stringer, 2000). Countries with agriculture as their economic backbone need to find means to sustain their economy through adaptation strategies and by mitigating the effect of climate change, so as to improve household income through increasing productivity of crops, livestock and dairy products.

The direct as well as the indirect impacts of climate change, affect the production level of every sector in a given economy; primarily, the agricultural production potential, including the animal productivity (meat and milk), of the agriculture sector is highly affected. According to Kaiser (1993), agriculture takes the leading role among the many systems which are expected to experience alterations as a result of climate change. The productivity of major crops, for example, will be lowered due to occurrences of high temperature during the reproductive period (‘Teixeira, Fischer, vanVelthuizen, Walter, and Ewert, 2013). Kaiser (1993) further stated that the vulnerability of agriculture is technically complicated because of the changes in temperature, precipitation and solar radiation that have a direct impact on agricultural production levels. The effect of climate change is expected to influence crop and livestock production, water balance, raw material supplies and other components of agricultural systems (Adams, Hurd, Lenhart and Leary, 1998).

Ethiopia is still one of Africa's poorest countries with a GDP per capita of USD 380. Ethiopia's economy is highly specialized in agriculture contributing more than 40% to GDP, and 70% of employment is still concentrated in agriculture (FAO, 2016). It's high dependence on this sector makes its economy vulnerable to climate change. Delink et al (2017) stated that, countries that have larger domestic markets and more diversified trade patterns can absorb climate shocks better than countries that are more specialized. Ethiopia's trade deficit amounts to almost 20% of GDP. In particular, to sustain its high growth rate, Ethiopia relies heavily on imports of oil, cement, and other primary goods.

The more a country depends on primary products export in the international market, the higher will be its vulnerability to climate change damages and the more susceptible to lose its competitive advantage. Ethiopia have shown remarkable economic performance, however still lacks behind in the international market. It has a negative trade balance and in 2018 it devaluated its currency relative to the US dollar. Although, this will make Ethiopia's goods and services cheaper in the international market, production will not cease to be affected by climate change which will adversely impact trade flows. Hence, any policy decision excluding the international trade consequences of climate change will be misleading.

1.2. PROBLEM STATEMENT

In the midst of booming investments for almost every sector and an average GDP growth rate of 8%, international trade is projected to foster for African countries. Trade, on the other hand, is expected to outpace growth in global gross domestic product (GDP) in the coming decades. International trade unequivocally depends on the health of sectors in a given economy, specifically on the comparative advantage of the trading country. For Ethiopia, a Sub-Saharan African country, international trade is relatively highly dependent on the performance of the agricultural sector, which is vulnerable to variability's in climatic events. However, the industrial sector of the country has recently been given a push upwards by policy makers with the intention to be more competitive in the international market and less vulnerable to deteriorating terms of trade.

Climate change is projected to affect the rate of economic growth through adverse impacts on natural system, infrastructure and productivity (Kreft et al., 2010). Continued increase in greenhouse gas (GHG) emission in the atmosphere will alter the climate system (Inter-governmental Panel on Climate Change, 2013). This alteration of the climate will have economic consequences through changing production and consumption patterns and hence on international trade. The intergovernmental panel on climate change (IPCC) identified the supply and distributional channels, on which international trade depends on, as being dangerously at risk of damage from climate change caused events such as rising sea levels. Climate change also affects the pattern and volume of trade flows by altering the comparative advantage of countries. It is an important step to study the synergies between international trade and climate policies for a trading country. Dellink et al. (2017), suggested that countries be aware of the impacts of climate change on international trade in-order to design climate and trade policies that are aligned and avoid the worst climate impacts at the least cost. This paper aims focused on the following research question:

- What are the international trade consequences of climate change for Ethiopia?

1.3. RESEARCH OBJECTIVES

The main aim of this study is to:

The overall objective of this paper is to examine the macroeconomic consequences of climate change on international trade as influenced by changes in temperature and precipitation.

Specific Objectives:

The specific objectives in this study are

i. Discuss the impact of climate change on the revealed comparative advantage of Ethiopia.
ii. Policy recommendations and suggestions for further studies.

1.4. SIGNIFICANCE OF THE STUDY

Ethiopia has initiated a Climate Resilient Green Economy (CRGE) strategy in 2011 planning to reach a middle-income status by 2025 based on carbon-neutral growth. The CRGE strategy is included in the Growth and Transformation Plan (GTP), where such green growth requires increasing agricultural productivity, strengthening the industrial base, and fostering export growth. This study aims to quantify the impact of climate change on international trade of Ethiopia. The findings of this study will lay a path for further studies on damages of climate change on the exports and imports of Ethiopia, as well as project the directions of impacts of climate change on international trade of the country.

1.5. LIMITATION OF THE STUDY

This paper only presents results from one single model and baseline. It Is also the limitation of this paper that it presents one climate scenario in contrast to different climate models. Ideally robust quantitative insights and a more elaborate modelling analysis, using multiple scenarios on the major modelling assumptions, would produce relatively robust analysis.

1.6. ORGANIZATION OF THE THESIS

Conclusively this thesis comprises five chapters. Chapter one deals with the introduction part that includes background, statement of the problem, and research objectives. In chapter two previous works on the impact of climate change on economic performances in general and on international trade in particular was addressed. Chapter two begins with reviewing related literatures and include historical, theoretical and empirical reviews. In chapter three, the study area description and research methodology are presented including data source and variable description, model selection and methods of analysis. Results and discussions of the findings are presented in chapter four in the form of tabular and graphical representations with their interpretations. Finally, in chapter five conclusions and policy implications are presented.

CHAPTER 2: LITERATURE REVIEW

2.1. INTRODUCTION

This chapter gives a summary of relevant literature, including empirical findings on the influence of climate change on international trade. The importance of aliening policies of international trade with climate change polices as well as reviews on important climate change agreements in relation to international trade is also part of the discussion in this chapter.

2.2. CLIMATE CHANGE

Climate change, according to Intergovernmental Panel on Climate Change (IPCC), is defined as a persistent change in the state (mean and/or the variability) of the climate that can be identified by changes in its properties. It refers to any change in climate over time, whether due to natural variability or as a result of human activity. Briefly defined, climate change could be taken as a persistent change in the properties of climate for a prolonged period. According to the United Nations Framework Convention on Climate Change report (UNFCC, 2011), climate change refers to the alteration of climate that is attributed directly or indirectly to human activity and which changes the composition of the global atmosphere. Further, UNFCC (2011) suggests that these anthropogenic pressures on climate variables have increased in a multidimensional way due to factors pressurising earth, affecting natural resources and ecological balance. Stern (2007) confirms the anthropogenic impacts to earth's environment stating that climate is rapidly changing mainly due to increased greenhouse gases (GHG) caused by human activities. IPCC (2001), stated that evidence shows that over the past 50 years the warming observed is mainly due to human activities. Rising level of GHG will increase earth's climate warming through increasing the amount of sunlight trapped in the atmosphere (Stern, 2007).

Climate change is undoubtedly one of the biggest challenges that the world faces today. Recurring droughts in many parts of the world, El Niño events, and the persistent and increasing heat stress are all indications that the earth's environment has changed, and according to the IPCC (2007), this time the changes are anthropogenic. Whether caused by human beings striving for economic growth or by natural causes, every country has to deal with the decision of how to adapt to the changes. Newell and Bulkeley (2010) argued climate change is not just a phenomenon in one country but is rather a global issue. They suggested that this global effect comes from the physical nature of the problem; that is, emissions in one place and time contribute to increasing atmospheric concentrations, which in turn will have impacts across the globe. According to IPCC (2007), the concentrations of carbon dioxide, methane, and nitrous oxide in the atmosphere have increased strikingly as a result of human activities. Under such high levels of these greenhouse gases, thorough research and development about how to live and adapt, by growing crops that can tolerate heat and extreme weather must not be taken for granted.

A drastic rise of GHG emissions (CO_2 emission specifically) have been noticed in the last decades (Onder, 2012). Data from the world bank data base confirms Onder (2012) conclusion as the CO_2 emission level for Sub-Saharan Africa shows an increasing rate relative to the OECD countries emission levels where CO_2 emission shows a declining trend (figure 1 and figure 2).

Figure 1: Emissions and output Sub-Saharan Africa

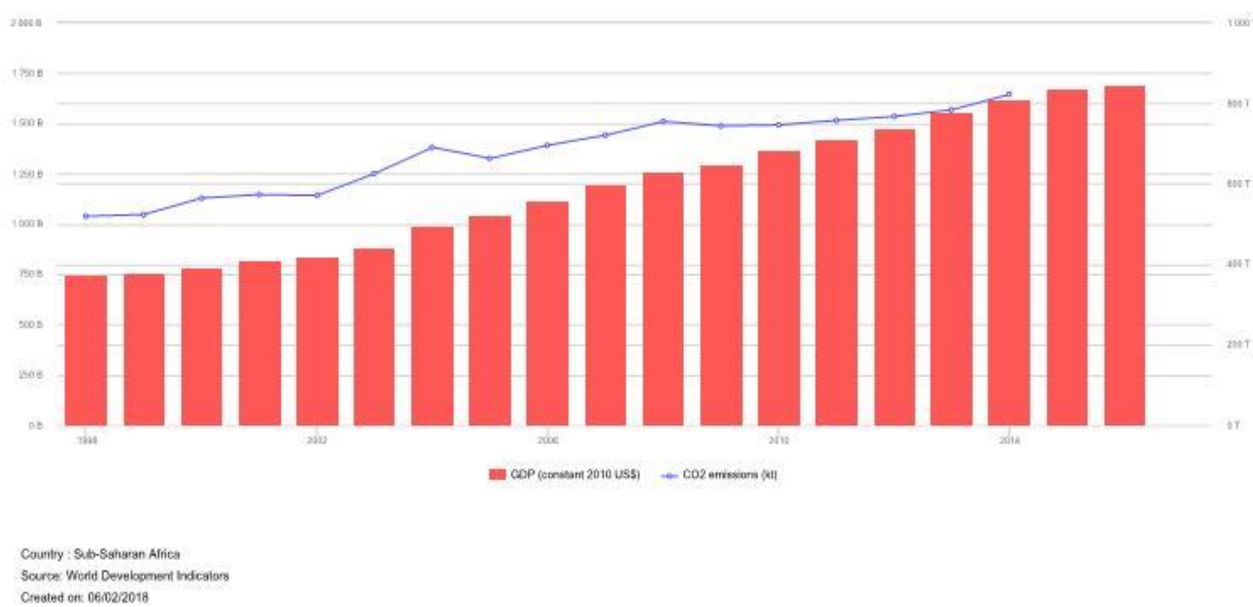
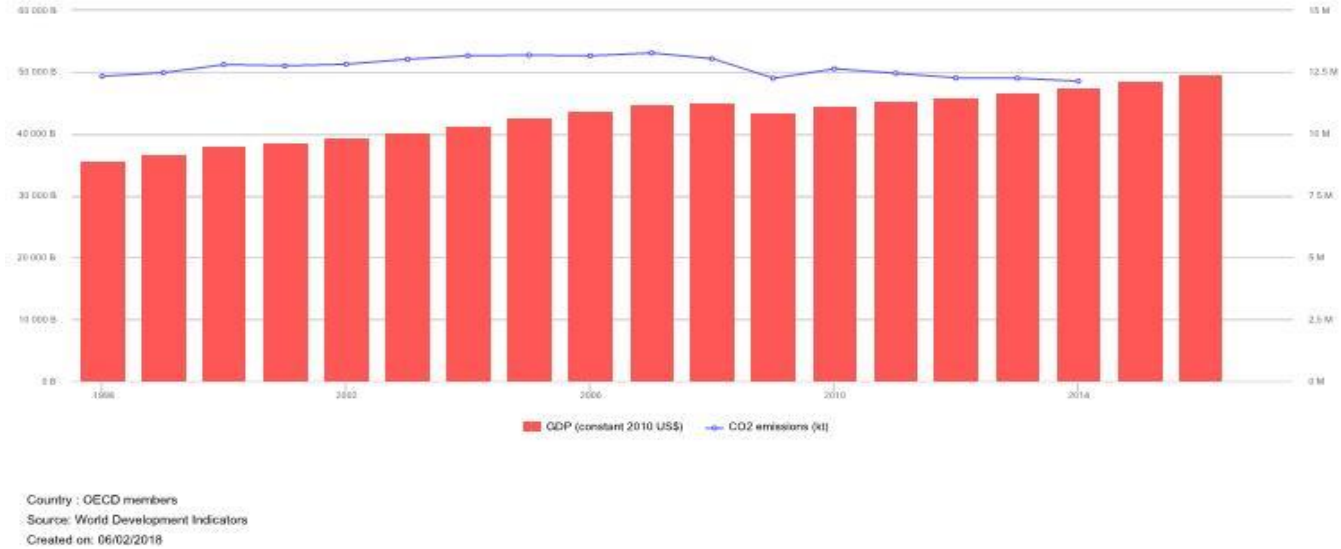
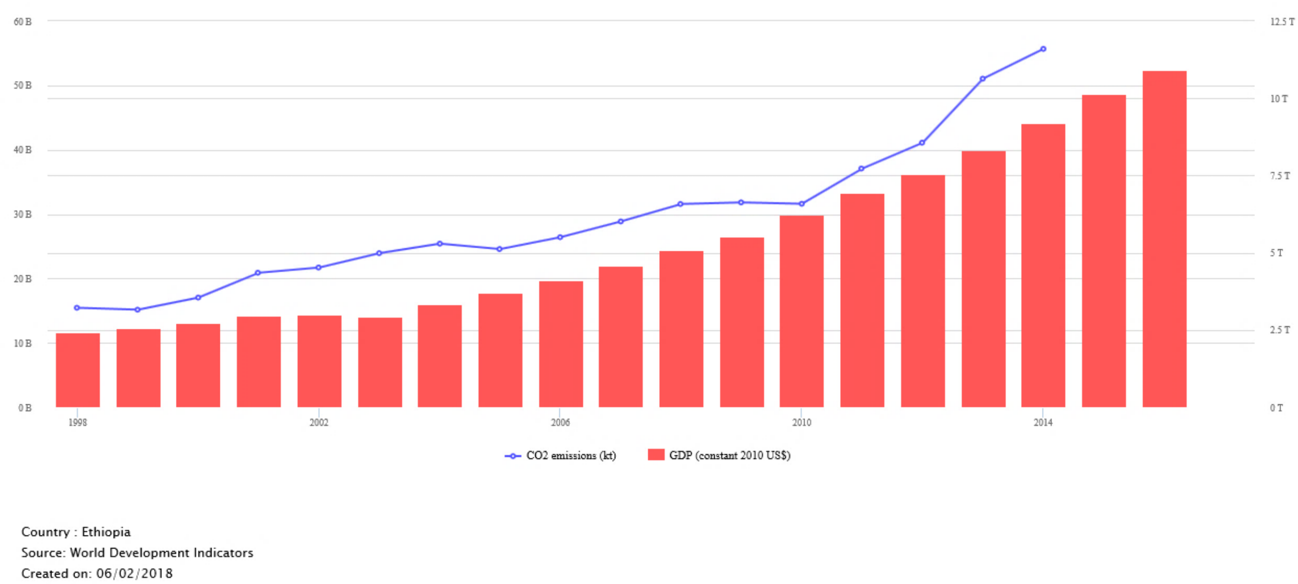


Figure 2: Emissions and output OECD countries



Ethiopia's GDP has shown an astonishing growth mainly due to the construction and investment booms, and with-it CO_2 emission have increased at a faster rate. The world bank database shows that for Ethiopia CO_2 emission has an increasing trend particularly after 2010 growing emission rate can be observed (Figure 3).

Figure 3: Emissions and output for Ethiopia



Economic productivity – the efficiency with which society transforms its human and other natural resources into new goods or services – is a key outcome in any society because it has a direct impact on individual well-being (Burke et al., 2015). Climate and weather influence activities in both agricultural and non-agricultural productions. However, as Burke et al. (2015) state, it remains poorly understood how the impact of climate change aggregates within complex human societies to affect overall economic productivity. Distinguishing these influences of climate change on the economy remains an essential problem, in the emerging field of coupled human–natural systems. This has implications for our understanding of historical patterns of human development and for how the future economy might respond to a changing climate.

Average surface air temperature so far this decade is about 0.9 °C higher than they were in the 1880s. According to Burke et al. (2015), if future adaptation imitates past adaptation, unmitigated warming is expected to change world economy by reducing average global incomes roughly by 23 % in 2100. This contributes to the widening global income inequality, relative to scenarios which do not pertain to climate change. Labour supply, labour productivity, and crop production all decline when temperature thresholds reach between 20 °C and 30 °C (Burke et al., 2015). Increasing temperature is a challenge to economic productivity and efficiency, which in turn weakens the works on poverty alleviation and food security.

Many studies have argued that climate change has an adverse and differentiated consequence on sectors of the economy, particularly on the agricultural sector (Calil et al., 2012; Key et al., 2014). Climate change is projected to affect the rate of economic growth through adverse impacts on natural systems and resources, infrastructure, labour productivity, and reduced income opportunities (Kreft et al., 2010). In contrast to these arguments, Deschenes and Greenstone (2015), using a country-level panel data file from the Census of Agriculture, developed measures for the impacts of climate change on the profits from agricultural operations that accrue to the owners of land. They discovered that climate change could actually benefit some owners of agricultural land positively by leading them to earn $1.3 billion (in 2002 dollars) or 4% in a yearly increase in agricultural-sector profits. This, however, could only be possible if farmers were to take appropriate adaptation methods and use crops which could stand strong against changes in climate, which is not the case for most developing countries.

The change in climatic factors alone are unlikely to verify winners and losers, as the vulnerability differences and adaptation strategies which are taken can notably shift the outcome for any of the changes (O'Brien &Leichenko, 2000). Furthermore, O'Brien and Leichenko (2000) explain that when it comes to climate change, a win might refer to any net advantage from changes in temperature, rainfall, or climate variability where such advantages could be measured by increased productivity.

Climate change mostly has a negative impact in many areas of the world (Gregory et al., 2005), but it has a positive impact for a limited period of time by providing a favourable air temperature for plant and animal life (Gornall et al., 2010; Thuiller et al., 2005). For instance, the increase in atmospheric temperature of the temperate region provides the region with a longer growth period and also increases in atmospheric CO_2 level, which will serve as additional nutrient for trees growing in the area (Hardy, 2003; Gornall et al., 2010). However, adverse impacts of climate change are more dominating than its advantages (Munasinghe& Swart, 2005; Hardy, 2003). The 'winners versus losers' concept is said to be counter-effective when it comes to attempts to achieve global harmony or agreements in decisions on climate change. This is particularly the case where most of the world's population have very few alternatives to adapt or mitigate climate change, and thus the 'winners versus losers' concept is unconvincing and to some extent illogical.

Multiple factors are responsible for climate variability and climate change, and are mainly anthropogenic in nature (Hardy, 2003; UNFCC, 2011). The pressure from human beings on the climate system is apparent, and recent anthropogenic emissions of greenhouse gases are the highest in history (Pachauri et al., 2014). Variations in many extreme weather and climate events have been observed since the year 1950, including changes which have been linked to human influences. Such changes include events such as decreases in cold temperatures and increases in warm temperature extremes, increases in sea levels, and increases in the amount of heavy rainfall events in many of the regions (Pachauri et al., 2014).

Climate variability and climate change are expected to disturb sustainable economic growth, make poverty reduction more difficult, increase the inequality gap, further erode food security, and extend existing and even create new poverty traps (Pachauri et al., 2014). Increased greenhouse gases are furthermore projected to increase the dislocation of people, particularly in developing countries with low incomes (Pachauri et al., 2014). These displacements can indirectly increase possibilities of conflicts and violence by intensifying well-documented drivers of conflicts, such as poverty and economic shocks. Political issues with respect to natural resource management are also crucial to any government in the world because they determine the existence and extent of strategies for solving problems associated with climate change (McCright&Dunlap, 2011).

Global warming creates extremes of precipitation in areas near each other, and an increase in precipitation causes storms (Lonfat et al., 2004). It can also result in drought by relocating the precipitation, resulting in a lack of rainfall, and an increased temperature (Gregory et al., 2005). The other reason is that global warming cause's oceanic evaporation and soil erosion, resulting in many problems (Solomon et al., 2007). Some other effects of global warming on the livelihoods of human being are its effects on ecological niches (Walther et al., 2002) and its creation of complementary conditions for the spread of invasive plant and animal species (Gregory et al., 2005; Garrett et al., 2006; Thuiller et al., 2005).The number of newly emerging diseases are increasing from time to time (Algore, 2005; Joly et al., 2004) and vectors for emerging infectious diseases, like rodents, mosquitoes, lice, fleas, snails, ticks and bats, are expanding their ranges (Gregory et al., 2005; Pascual et al., 2006; Lafferty, 2009; Patz et al., 2005).Furthermore, the re-emergence of formerly eradicated diseases, like Evian flu and the West Nile virus, is being observed (IPCC, 2001; Obi et al., 2010).In addition, ground and marine species loss, both plant and animal, is progressing at a rate much higher than the normal rate (Balmford et al., 2005; Thompson et al., 2009). Global warming also reduces water availability (Munasinghe&Swart, 2005; IPCC, 2007; Gore, 2006).

2.3. CLIMATE CHANGE AND AFRICA'S AGRICULTURAL SECTOR

The agricultural sector is one of the economic sectors of a country that is closely linked with, and highly dependent on, the environment. This makes it one of the most vulnerable sectors expected to be affected by climate change. Agriculture takes the leading role in undergoing changes as a result of climate change (Kaiser, 1993), technically because changes in temperature, precipitation, and solar radiation have a direct impact on crop and livestock production. Agriculture, as one sector of the economy which is directly and indirectly linked to climatic variables, is likely to be affected by climate change (Fisher et al., 2015).

The IPCC (2014) projects Africa to be highly susceptible to major changes in climate. With its high dependence on agriculture, Africa is already a continent prone to be adversely impacted on by the outcomes of climate change. One third of the African population is expected to live in drought-vulnerable areas and about 220 million people face the impacts of drought each year (Nkondze et al., 2013). African countries are indeed vulnerable to greater impacts of climate change and variability, in part because they often lack adaptive ability or strategies. Because large proportions of the population are greatly reliant on climate-sensitive livelihoods like agriculture, the continent's vulnerability to climate change will increase (Nkondze et al., 2013).

African countries are faced with many challenges including poverty alleviation, reduction of illiteracy, weak institutions, low levels of health care, poor access to resources (including forests), desertification, and land degradation. All of these exacerbate the impact of climate change on the continent (UNDP, 2007). The African Climate Policy Centre (ACPC, 2011), has underlined the challenges African farmers are currently facing due to climate change (let alone expected future increases in temperature):

"Currently, at 0.74 °C of warming, African farmers and pastoralists are seeing changes in the timing of rains, in the severity of rains, in the temperatures they and their crops and animals are exposed to, and in the progressive drying of their soils. Food production is already threatened by the temperature rise of the last century, and the committed warming due to greenhouse gas emissions of the last decades." (ACPC, 2011)

Climate variability, through its impact on agriculture's output, is anticipated to erode food security. According to Pachauri et al., 2014 due to expected climate change by the mid-21st century, global marine biodiversity reduction in many regions will challenge the sustained provision of fisheries productivity and other ecosystem services. Furthermore, Pachauri et al., 2014 explain that global temperature increases of ~4 °C above late 20th century levels, together with increased population might put pressure on food security. Climate change is also expected to reduce renewable surface water and groundwater resources in most dry subtropical regions, thus increasing competition for water among sectors. The impact of climate change on the agriculture sector of the African continent will increase the challenges faced in the efforts to achieve food security. Increasing population expansion may continue to be one important hindrance to achieving improvements in food security for some countries, even when the world's people as a whole cease growing sometime during the present century (Thornton, 2010). According to Haen (2003), more than 814 million people in emerging countries are malnourished, of whom 204 million live in countries of sub-Saharan Africa.

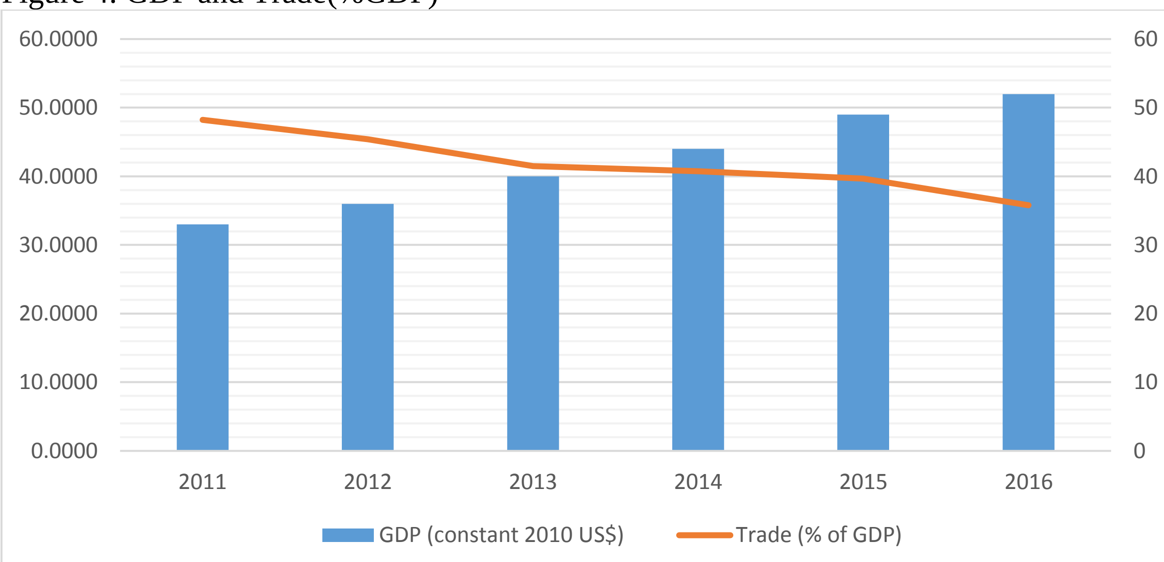
Worldwide, Africa is the only continent where populations are projected to continue increasing throughout the twenty-first century (United Nations International Children's Emergency Fund, 2014). The United Nations International Children's Emergency Fund (UNICEF, 2014) states that with 1.2 billion people living in Africa, and expected to double by 2050 to 2.4 billion, food security is and will continue to be one the major challenges faced by the continent. With the growing population and projected economic growth of the continent, demand for dairy products will increase. According to Rakotoarisoa, Iafrate and Paschali (2012), both dairy and other livestock products have a high income-elasticity of demand, especially at low-income levels. This means that increases in income lead to large increases in demand for livestock products. Thus, per capita income growth will translate into significant increases in demand for livestock products.

Ethiopia has an agricultural sector that is dependent on climatic factors such as, temperature and rainfall. At the same time Ethiopia has an international trade which is dependent on the export of agricultural raw materials, and hence, the future of international trade will have a direct correlation with climate change and extreme weather events. The next sub-sections will discuss literatures on the relationship of climate change and trade.

2.4. INTERNATIONAL TRADE IN ETHIOPIA

International trade is thought as the great hope for poverty alleviation with the ever-growing globalization (Reinert,2005). Trade can contribute to poverty alleviation by expanding markets, promoting competition, and raising productivity, each of which has the potential to increase the real incomes of poor people (Reinert, 2005). Ethiopia has increased its involvement in international trade, although less rapidly than other countries (Reinert, 2005). Trade as a percent of GDP has declined from 48.2% in 2011 to 35.8% in 2016 (Figure 4). Trade to GDP ratio is the proportion of aggregate import and export over time to GDP over time. The decline of Trade as a percentage of GDP is hence, attributed to either the reduction in the country's export or import.

Figure 4: GDP and Trade(%GDP)



Data from database: World Development Indicators

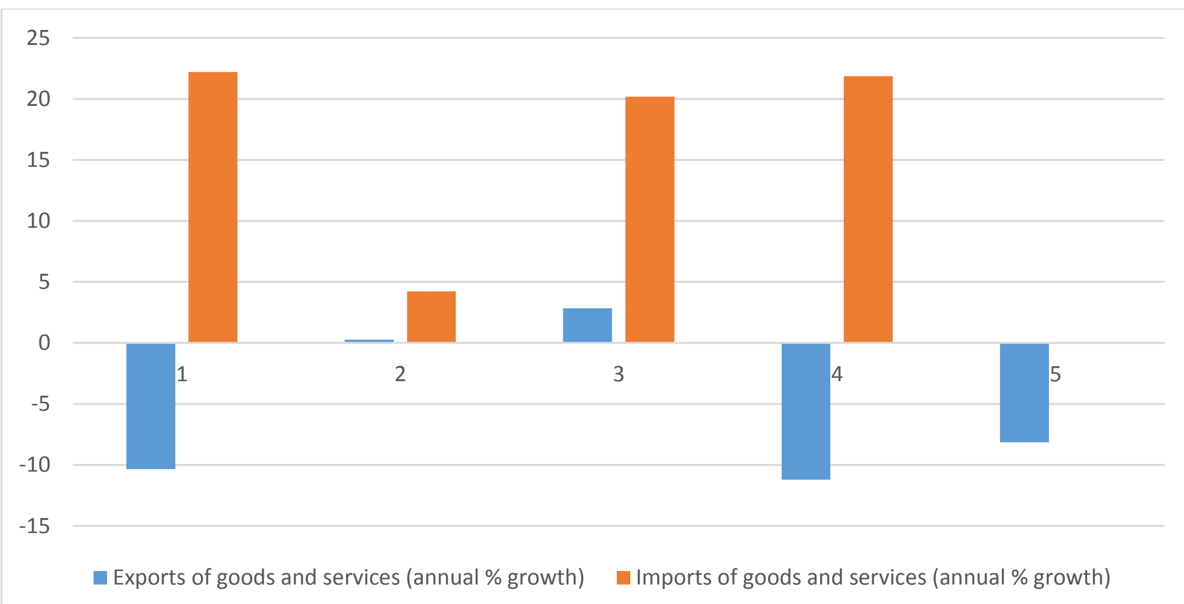
There could be different reasons for the continues decline of trade (%GDP), one plausible reason is the growth of GDP outpace that of trade (Export plus Import). Another plausible reason could be the adverse impacts of birr devaluation which took place in 2013 (Eshetu, 2017; Mariam and Fekadu, 2016).

Table 1: Trade to GDP ratio

Year	Exports of goods and services (% of GDP)	Imports of goods and services (% of GDP)	Trade(%GDP)
2011	16	31	48
2012	14	31	45
2013	12	28	41
2014	11	29	41
2015	9	30	40
2016	8	27	36

Relative to Exports share of GDP the share of imports to GDP have been fairly stable (Table 1). To look at the growth rate of Exports and imports creates a clearer understanding for a better economic analysis. Ethiopia's Export growth rate shows a negative value in 2011 (Figure 5), although international monetary fund (IMF) projects the export of goods growth rate to reach to 11.41 % in Dec 2018 and 12.12% in Dec 2022.

Figure 5:Growth rates of export and Imports



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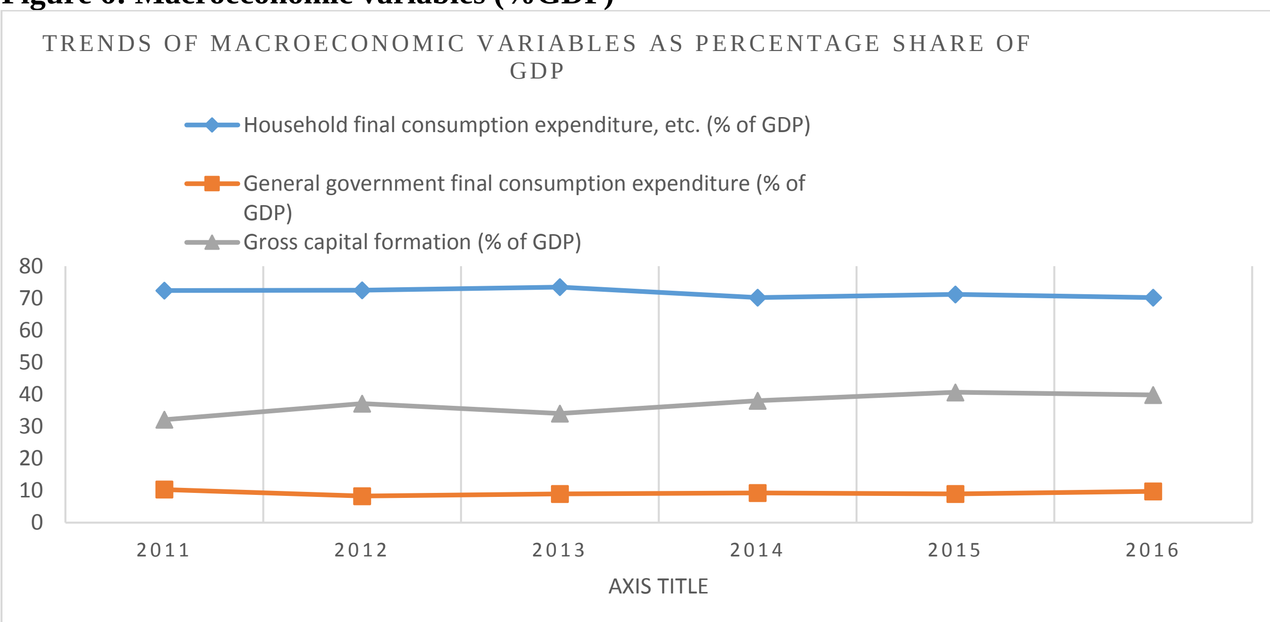
Primary products take up the leading share of exports for Ethiopia. According to Reinert 2005, Primary commodity dependence has a number of drawbacks from the point of view of poverty alleviation. To list some are the secular, downward trend in commodity prices, the escalating protection in primary commodity markets in developed countries and the monopolistic pricing along commodity chains practiced. This dependence problem was apparent as coffee export revenues fell by over US$100 million between 1999 and 2001 as coffee prices fell to a 30-year low (Reinert, 2005). It is important to look at the share of other macroeconomic variables which may have contributed to the decline in the share of trade in countries GDP. As shown in figure 6, the macroeconomic variables remained fairly stable in the period from 2011-2016, with the exception of gross capital formation which showed an increasing trend attributing to the increase in public investment in infrastructure.

Figure 6: Macroeconomic variables (%GDP)



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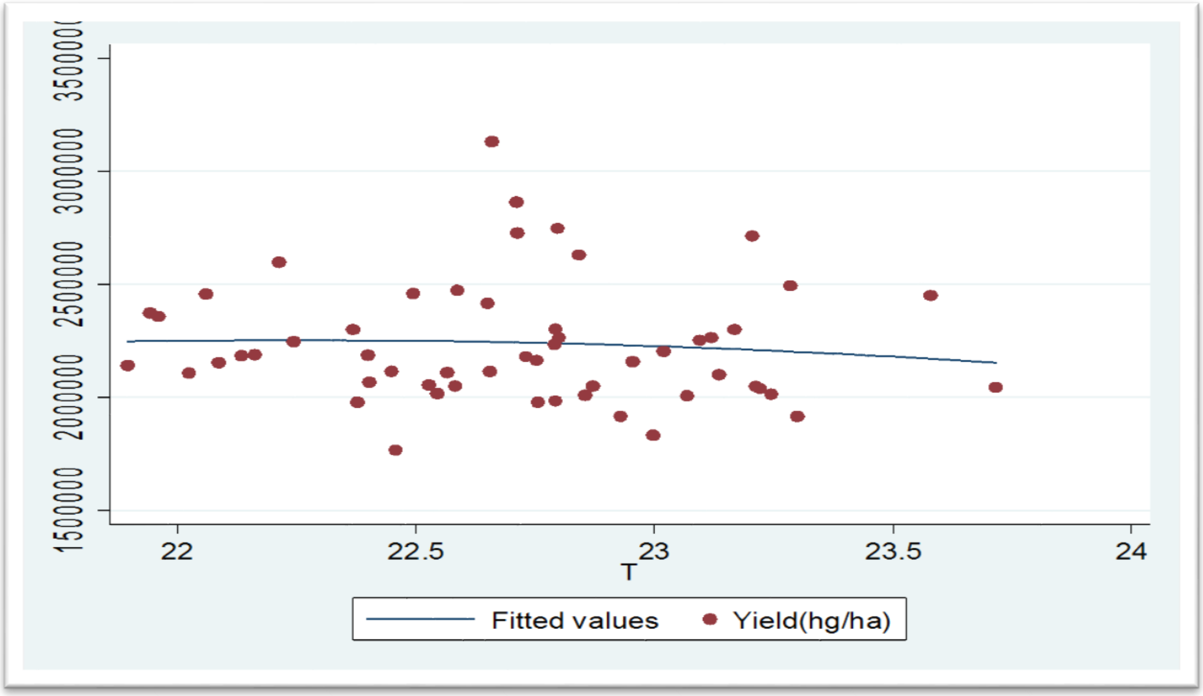
2.5. TRADE AND CLIMATE CHANGE IN ETHIOPIA

Agriculture takes the leading role in undergoing changes as a result of climate change (Kaiser,1993). Estrada, Eakin and Villers (2006), estimated the potential impacts of climate change on coffee production by applying statistical analysis and different climatic conditions for Veracruz, Mexico. They found a significant 34% reduction in coffee production due to climate shocks by 2020 and concluded that coffee production might not continue to be a viable economic activity for producers. Ethiopia's agricultural sector contributes about 41.4% to GDP and 84% of total exports. FAO (2014) states that agriculture as the main sector of the economy and that exports are almost entirely composed of agricultural commodities. Coffee and hides and skins are the major composites of Ethiopia's Exports. While imports are mainly composed of manufacturing Products, oil and medicinal products. As susceptible sector to fluctuations in climatic variables such as temperature and rainfall, changes in production due to climate change will influence the country's trade and comparative advantage. Taking 50 years of agricultural yield data from FAO statistics and temperature data from world bank group climate change knowledge portal, figure 7 depicts that crop production has a declining trend with rising temperature. It is off-course, imperative to look at the impact of climate variability on each of the major crops, however, it is beyond the scope of this study and is suggested for further studies.

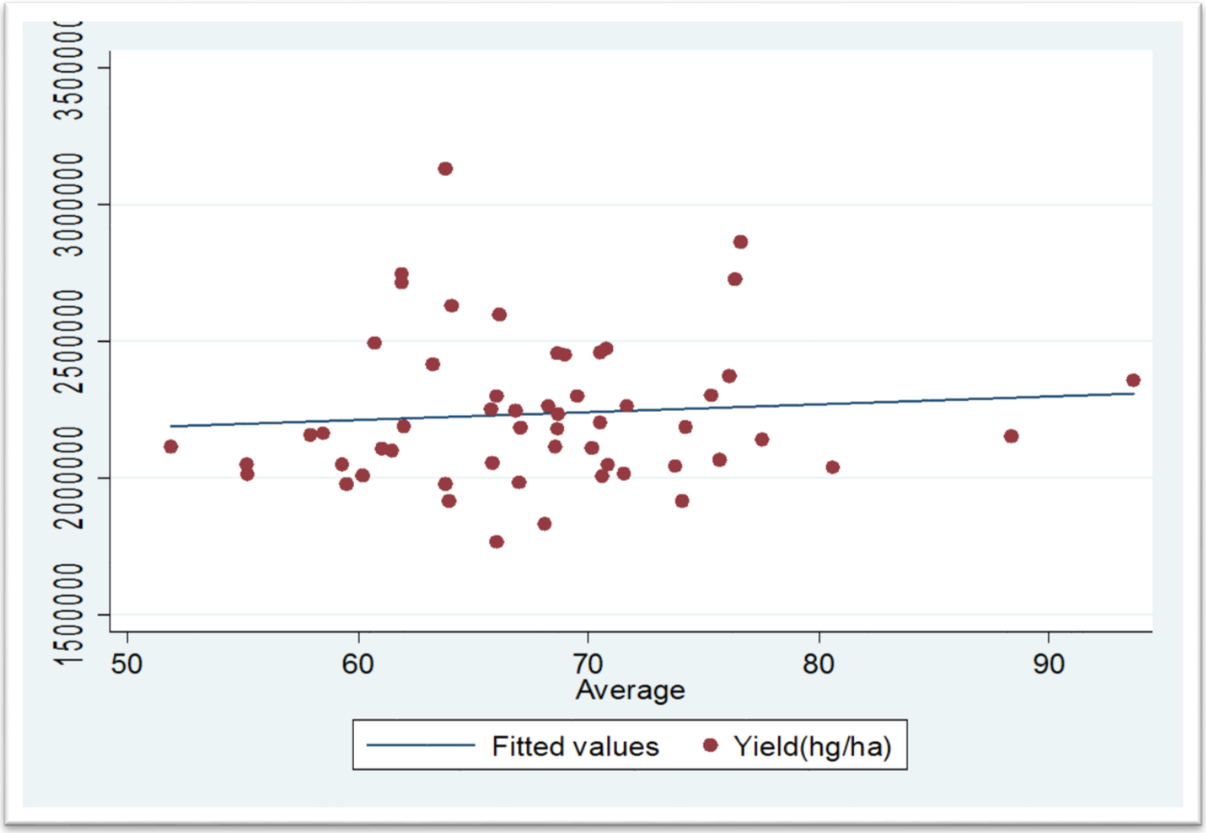
Figure 7: Tradable agricultural yield and Temperature(^{0}C)



Source: Author's calculations

Rainfall is a crucial element for Agricultural production, practically for small holder farmers who depend on rainfall for production. The trend of crop production in Ethiopia shows a rise with an increase in rainfall (figure 8).

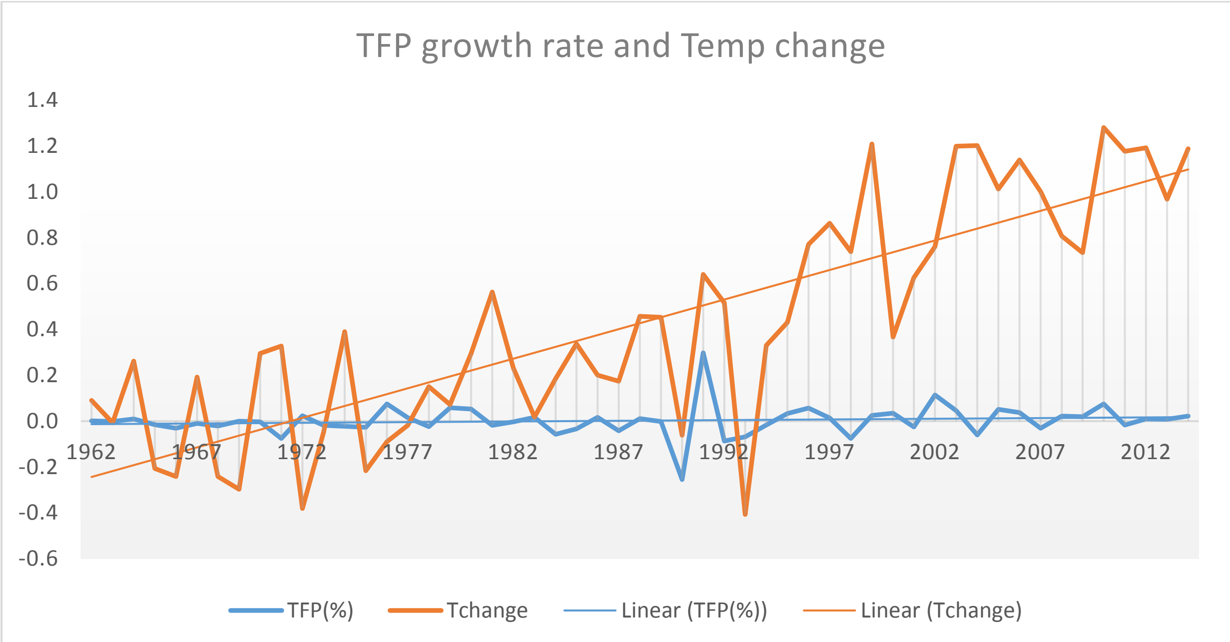
Figure 8:Rainfall and Agricultural yield



Source: Author's Calculation

Climate change also impacts agricultural production by impacting agricultural total factors of production (TFP). Letta and Tol (2016), estimated the relationship between annual temperature shocks and TFP growth rates for 60 countries (including both developed and developing) between the periods of 1960-2004 by using Penn World Tables dataset. They discovered that temperature shocks affect TFP negatively only in poor countries with a reduction in TFP for about 0.1%. For Ethiopia temperature change have been increasing through the periods 1962 to 2014 (FAO stat data, 2018), while TFP have shown a slight increase since the political transition period of 1991 for Ethiopia (Figure 9). This slight increase in TFP is evident through the rise in the use of fertilizers and the increase in commercial farming which gave rise to agricultural production.

Figure 9:TFP growth rate and Temp change in Ethiopia



Source: Author's calculations

Ethiopia aims to increase its export revenue from $3 billion in 2016 to $16 billion by 2020 (Onder, 2012). To achieve this goal Ethiopia has been working to account 25% of its export revenue to manufacturing sectors, moving from the exports of primary goods that have deterioration terms of trade. The industrial park project aims to attract foreign direct investment through its export-led and labor-intensive manufacturing sectors. Processing of Agricultural commodities, leather, textiles, tobacco, garment production and beverages are some of the manufacturing activities which are to be included. Ethiopia has also initiated a Climate-Resilient Green Economy (CRGE) with the objective of achieving targeted economic growth while keeping greenhouse gas emissions low. It is vital to have a well-designed policy that synergies climate change scenarios with international trade policies. Dorege et al. (2016), stated that international trade can be looked at as something that could potentially help to achieve transformative change in climate policy. The report of United Nations Conference on Trade and Development (UNCTAD, 2015), suggested that the most direct way to reduce GHG emissions in an economy is to establish a mix of policies and institutions that progressively green a nation. Hence, with the aim to increase its international trade and having initiated a green economy strategy, a comprehensive analysis on the intercession between climate change and international trade is central.

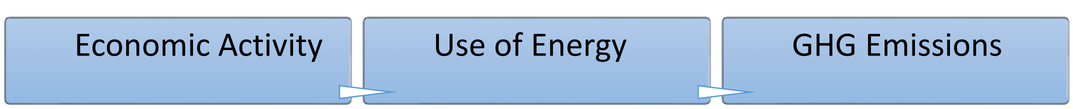
2.6. TRADE, CLIMATE CHANGE and COMPUTABLE GENERAL EQUILIBRIUM MODEL

Tamiotti et al. (2009), studied the impact of trade on the environment. They suggested that the overall impact of trade on GHG emission cannot be determined a priori but rather studies should include the scale effect, the composition effect and the technique effect in order to analyze the net impact of trade. They examined the intersection between climate change and international trade from different perspective and highlighted that mitigation measures should be designed and implemented in a manner that ensures trade and climate policies are mutually supportive.

Trade-climate related theories suggest that the marginal change in trade effects on greenhouse gas emission levels in three channels: the scale effect, the composition effect, and technique effect (Copeland and Taylor, 2003). The net change in aggregate emission is determined by the interaction of these three effects (Onder, 2012). Scale effect has a positive effect where with increase in economic activities there will be an increase in emissions. The composition effect depends on the share of goods in production. If the goods are greenhouse-gas intensive, then emissions will increase. Technique effect refers to the change in emission due to methods of production. According to Onder (2012), trade can reduce emissions per unit of output by increasing productions of environmentally good products or changing techniques of production.

For the last decade Africa has experienced an average growth rate in GDP of 5-6% (Zamfir, 2016). With this growth international trade has also experienced a rapid growth and is projected to outpace economic growth rates. Trade openings can have an effect on the environment through three channels (Copeland and Taylor, 2003; Tamiotti et al., 2009).

The first of these principals is referred as the Scale Effect which is the expansion of economic activity as a result of trade opening and its effect on GHG emissions.



The second channel through which trade brings changes to the environment is known as the Composition Effect. It refers to the way that trade opening changes the structure of a country's production. The effect on GHG emissions will depend on whether a country has a comparative advantage in emission-intensive sectors and whether the sectors are expanding or contracting. If the sectors that are expanding less energy intensive, then the composition effect will have lower GHG emissions. Tamiotti et al. (2009) explains that the composition effect could be a response to changes in relative prices or a response to various environmental regulations between countries. The "Pollution haven hypothesis" suggests that emission-intensive industries will seek to relocate to countries with less stringent environmental policies.

The Technique Effect is the third channel through which trade impacts the environment and it refers to the technological advancements by which goods and services are produced in order to reduce emission levels. This decline in emission will result in two ways. One is by creating a market for environmental goods and services. The other one is related to the environmental Kuznets curve which suggests that an increase in income which leads to a higher demand for environmental quality and hence lower GHG emission. In addition to the three effects, Cosbey (2007) suggests that increased international trade will lead to increased GHG emissions through an increase in modes of transport.

The contribution of international trade to GHG emission and hence for climate change, as discussed above, is an important aspect to consider in policy designs. However, this study is focused on the analysis of the impact of climate change on international trade by considering the impact climate change has on the major export products of Ethiopia. The organization for economic co-operation and development (OECD) have been using ENV-Linkage model in order to project impact of climate change on international trade. ENV-Linkage model is a dynamic neo-classical general equilibrium model (CGE) built mainly on a database of national economies. It is an economic model that links economic activity to GHG emissions. This link is projected many decades into the future to analyze the impact of environmental policies in the long-run. Dellink et al. (2017), analyzed the direct as well as the indirect impact of climate change on international trade. For the indirect impact of climate change on international trade they used OECD's ENV-linkage model (CGE model), while they applied a qualitative analysis for the direct impacts of climate change. The results from the ENV-Linkage model simulations shows that climate change impacts will place a negative pressure on economies of almost all regions, particularly higher consequences in Africa and Asia, through reduced trade flows. They suggested that trade in agricultural commodities is relatively expected to be strongly impacted by climate changes. Cosbey (2007) portrayed the physical impact of climate change on trade which results from its impact on agriculture and other traded sectors. Hence, showed there is a two-way effect between climate change and Trade which requires a thorough analysis.

Amsalu (2016), assessed the economy-wide effects of Climate change-induced Productivity and labor supply shocks in agriculture for Ethiopia and found that agricultural output will fall, while price of agricultural commodities will increase. Mintewab et al., (2010) stated that the responsiveness the economy to climate shocks depends on its macroeconomic structure. They analyzed the economic impacts of climate-induced adjustments on the performance of he Tanzanian economy using CGE models and found that productivity impacts of climate change are limited until 2030, which is a slightly different finding than Amsalu et al., (2017) who assessed climate impacts in the Ethiopian economy. Gebregzibhre et al., (2015) analyzed the economic impacts of climate change-induced changes on the performance of Ethiopia's agriculture, using a countrywide computable general equilibrium (CGE) model and concluded that the impact of climate change to be benign until 2030, while it will become worse after. They further stated that, over a 50-year time, the projected reduction in agricultural productivity may lead to 30 percent less average income, in contrast to a scenario without climate change. Robinson et al. (2011) applied a dynamic CGE model to simulate the economic impacts of climate change towards 2050 and concluded that without any adaptation strategy investment Ethiopia's GDP will be lower by up to 10%. They further stated the importance of investing in adaptation strategies in restoring aggregate welfare to baseline levels.

Amsalu (2016), points out the importance of quantifying the economy wide impacts of climate change both for adaptation strategies and including climate-change issues in the development plans of Ethiopia. Aligning sectoral economic policies and climate change policies will allow policy implementations to be well planned and at the least cost (Delink et al., 2017; Amsalu, 2016). International trade is adversely affected by climate change and hence, aligned policy decisions are important. Amsalu (2016) concluded that imports of agricultural goods will increase while agricultural export do contract. While, exports of non-agricultural goods increase while their imports decrease which will affect the trade mix of the country.

A competitive international market requires countries to acquire a comparative advantage that is demand centered. While, it is imperative for countries to increase international trade, the fact is that climate change will impose a challenging future. Although, international trade is projected to increase in the coming decades, climate change will affect trade through different channels. Climate change is expected to impact infrastructures such as the transport through rising sea level and extreme whether events (Dellink et al., 2017). Increasing GHG emissions puts pressure on countries production as they constantly try to adhere to international agreements on mitigation of climate change. Trade will also have an impact on the environment through productions of energy-intensive goods and services that increase GHG emissions, particularly increasing CO_2 in the atmosphere. However, with the right trade and climate policies, GHG emissions will be reduced at the least cost. It is imperative for a country to have a thorough analysis on the interaction between trade and climate change policies in order to have a comparative advantage in international trade in the long-run.

This paper focuses on the impact of climate change on trade of goods and services as opposed to other traded items such as capital and labor.

CHAPTER 3: METHODOLOGY

3.1. INTRODUCTION

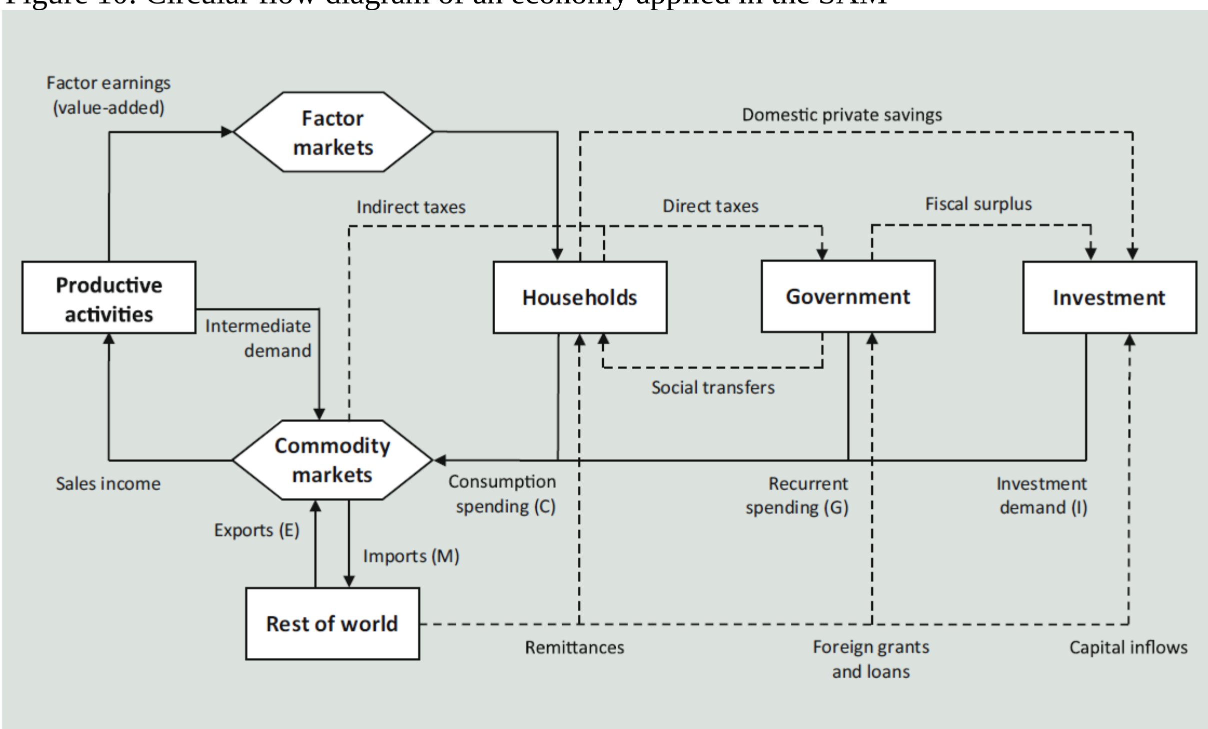
The main objective of this chapter is to describe the research methods applied for calibrating the impact of climate change on international trade for Ethiopia. As mentioned in the previous chapters the focus of this study is to calibrate the indirect impacts of climate change on trade which primarily result from climate change's impact on the production of goods and services through changes the efficiency with which factors of production of such as land, labor, and capital can be deployed. Changes in the agricultural factors of production of (i.e. land, labor, and capital) will affect production structure and trade specialization (Dellink et al., 2017). Hence, two methods are used for the analysis of the impact of climate change on international trade; the first is the econometric estimates which would alter the impacts of climate variables on agricultural total factor productivity (TFP). The second model applied is computable general equilibrium model (CGE) which calibrates the impact of climate change on trade for Ethiopia. The paper limits the modeling analysis to one probable scenario to shed light on how climate change will affect trade. Impacts on Comparative Advantage (CA) value is qualitatively discussed with analysis of the results from the CGE model.

3.2. SOCIAL ACCOUNTING MATRIX (SAM)

The social accounting matrix (SAM) is a complete, disaggregated and consistent economy-wide framework which represents the interdependence prevailing within the socioeconomic system (Thorbecke 2000; Lofgren et al., 2002). SAM comprises of many different activities and transactions of households, government and the rest of the world. As noted by Thorbecke (2000) there are three main features of a SAM. First, the accounts are represented as a square matrix; where the incomings and outgoings for each account are shown as a corresponding row and column of the matrix where the transactions are shown in the cells. Second, it is comprehensive, in the sense that it portrays all the economic activities of the system (consumption, production, accumulation and distribution), although not necessarily in equivalent detail. Thirdly, the SAM is flexible, in that, although it is usually set up in a standard, basic framework there is a large measure of flexibility both in the degree of disaggregation and in the emphasis placed on different parts of the economic system. Ideally SAM differentiates between activities of production and commodities, mainly allowing for an activity to produce multiple commodities (Lofgren et al., 2002).

For an economy wide analysis alternatively, SAM is preferably used as a conceptual framework to explore the impact of exogenous changes (Thorbecke, 2000). Hence, SAM becomes the basis for simple multiplier analysis and calibration of a variety of applied general equilibrium models. The basic framework of SAM is depicted in figure 10, where the transactions (income and expenditures) among economic agents are outlined.

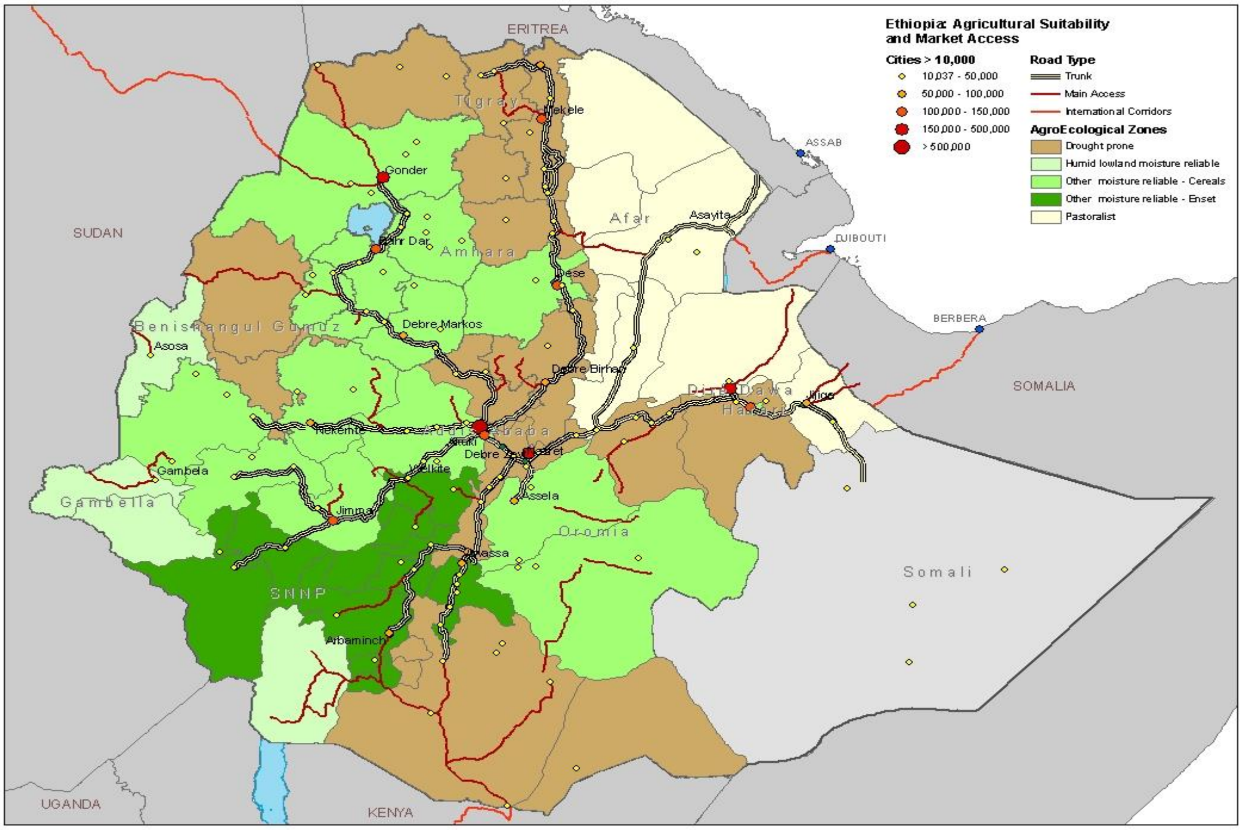
Figure 10: Circular flow diagram of an economy applied in the SAM



Note: the arrows show direction of payments
Source: adapted Breisinger, C., M. Thomas, and J. Thurlow. 2009

The 2005/2006 Ethiopian SAM (updated to represent the Ethiopian economy in 2009/10) produced by Ethiopian Development Research Institute (EDRI) is a comprehensive economy wide data sets used in this paper as a main dataset for calibration of the CGE model. The Ethiopian SAM comprises all the real income and expenditure flows for the year 2005/06. The SAM captures 77 agricultural activities, 64 commodities, 16 factors, trade and transport margins, stock changes, saving and investment accounts. In total it consists of 65 production sectors (24 agricultural, 10 agricultural processing, 20 other industry, 11 services). The Regional SAM is classified as the rainfall-sufficient, drought prone, and pastoralist.

Figure 11: The five agroecological zones in Ethiopia SAM



Source: Dorosh and Thurlow (2010)

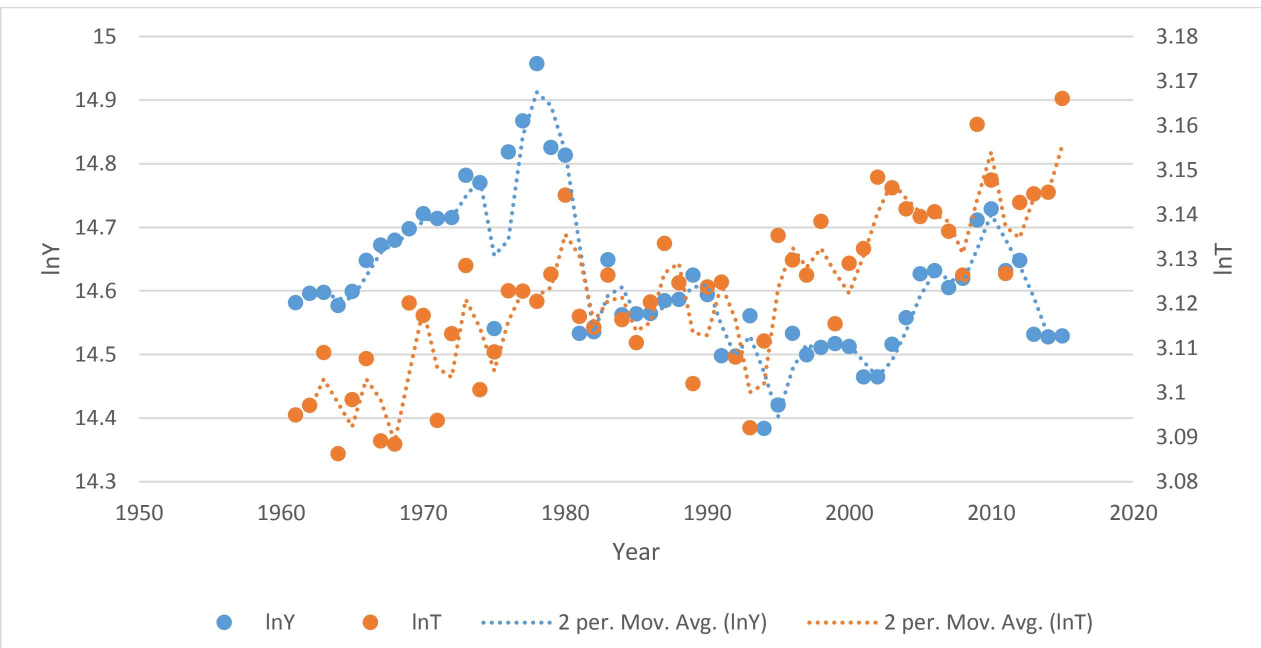
There is no specific account in the SAM representing climate change or any of the climate feathers. Thus, in order to analyze the economy-wide consequences of climate shocks one first has to estimate the impact climate variables have on factors of productions and then shock the parameter in the SAM by the resulting coefficient.

3.2. ECONOMETRICS MODEL

This paper adapted a multiple regression econometric model and a CGE model. The first model was based on the modeling approach applied by Estrada et al. (2006). It integrates climatic variables and economic variables which are determinants for tradable agricultural productions. The general regression model (Equation 1) includes a linear and quadratic forms of climatic means and other variables assumed to determine production.

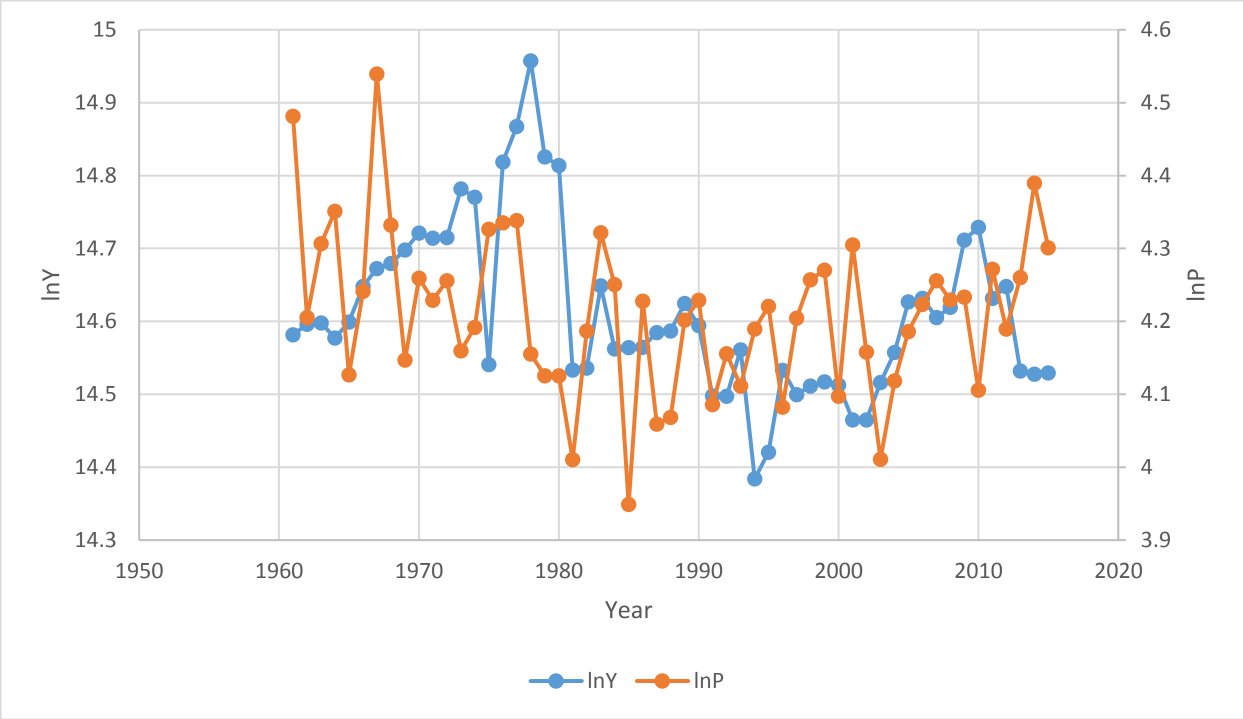
Before discussing the model, specifications applied it is important to first look at the evolution of yield and temperature over time. Plotting the log transformed of an econometric timeseries variable will give a better detection of trends and implication for distribution (Geda et al, 2012). There is clearly no linear relationship for both yield and temperature (figure 12). Temperature has an upward trend through time while yield seems to follow a declining trend due to many determinantal factors other than temperature rise.

Figure 12:Scatter plot of yield and temperature over time



Source: Author's calculation

Figure 13: Scatter plot of yield and temperature over time



Source: Author's calculation

Figure 13 shows the scatter plot of log-transformed precipitation and yield over time. The trend for both timeseries variables, is declining overtime. The outliers on both figure 12 and 13 predicts in which year was the lowest rainfall or the highest temperature recorded as well as the lowest and highest production.

Data for the climatic components were taken from the world bank climate change knowledge portal. For other Economic variables data was extracted from the world bank database and FAO stat data base. The data for agricultural total factor productivity was taken from the United States Department of Agriculture Economic Research Service (USDA-ERS) published in 2017. Even though a quadratic functional form generates multicollinearity problems, it works better for modeling the production response to changes in climatic variables than a linear specification. This is because the linear form would imply that there are no optimum values and that the effect of these variables over production is monotonic while the quadratic form will allow estimation of how production will be affected as we get farther from these optimum values (Estrada et al., 2006). The model specification in this paper follows the ones applied by Estrada et al. (2006). They suggested the use of the adjusted R-squared to decide whether to keep a variable in the model when multicollinearity problems arise and t-statistic becomes unreliable.

The econometrical analysis which was found to be necessary for the calibration of the parameters in the CGE model is:

$$\boldsymbol{TFPt = f(T, P, Ti, Pc)} \text{ ……………………………………………………...} \textbf{Equation 1}$$

Where:
TFPt= agricultural total factor productivity over time
T=average annual temperature
P= average annual precipitation
Ti= average seasonal temperature
Pc= average annual change in precipitation

It is important to estimate the impact of climate variables on agricultural factor productivity in order to look at the consequences of climate change on international trade. The most informative measure of agricultural productivity is TFP which takes into account all of the land, labor, capital, and material resources employed in farm production and compares them with the total amount of crop and livestock output (USDA, 2018). TFP differs from measures like crop yield per acre or agricultural value-added per worker because it takes into account a broader set of inputs used in production. TFP encompasses the average productivity of all of these inputs employed in the production of all crop and livestock commodities (USDA, 2018). The TFP used in this paper is extracted from USDA data base for the year from1962 to 2016.

“The Temperature Change domain of the FAOSTAT Agri-Environmental Indicators section contains data on observed mean surface temperature changes by country, over the period 1961-2017 with annual updates. The data provide information on monthly, seasonal and annual mean temperature anomalies, i.e., temperature changes with respect to a baseline period, 1951–1980. Data are based on GISTEMP, the Global Surface Temperature Change data of the National

Aeronautics and Space Administration Goddard Institute for Space Studies (NASA-GISS). The Temperature Change domain provides Member Countries with Climate-Change Relevant Statistics in support of national and regional agri-environmental analysis." FAOSTAT (2018).

The Reveled Comparative Advantage (RCA) indicator can also be used to show how changes to factors of production (induced by climate change damages in this case) affect gains and losses from trade that countries derive from domestic factor endowments (Dellink, 2015). Particularly RCA is an index which shows the relative advantage or disadvantage of a country in producing certain commodities. RCA is defined as the share of a region's exports of a set of commodities in the region's total exports relative to the share of the world's exports of these commodities in global exports. Although various mathematical models for measuring RCA value exist the most widely used is Balassa index (Granabetter, 2016). Technically the Balassa index used for country-sector Revealed comparative advantage is:

$$RCA = \frac{xij/Xallj}{Xiall/Xallall} \quad \textbf{Equation 2}$$

where xij denotes exports of product i by country j (Ethiopia) and 'all' refers to the relevant group of all products (i.e. all those that are exported).

3.3. COMPUTABLE GENERAL EQUILIBRIUM MODEL

The standard Computable General Equilibrium model (CGE) follows all the disaggregation's in SAM (Lofgren et al., 2002). According to Bernow et al. (1998) "CGE models are general models in that they represent the economy in its entirety, in-spit of its high level of abstraction and aggregation, as composed of a set of inter-related markets; CGE models are equilibrium models because they embody the assumption that each market clears, through the movement of prices that equate supply and demand; CGE models are computable in that they use equations specified with parameters that assume real values; (Typically, some parameters are based on econometric estimates reported on the literature, while others are computed when the model is calibrated to a set of benchmark data)". CGE models are useful because they depict the economy as a system of interrelated sectors, allowing the analysis of indirect effects. Their advantage over the earlier Input-

Output models, which rely on fixed coefficients, is that this is possible while allowing markets to respond to economic variables, if only in a fashion that aggregates across agents within a market (Bernow et al., 1998). Thus, CGE model is suitable for economy-wide analysis as they focus on linkages between economic activities and sectors (Dellink et al., 2017). CGE model is built as a set of simultaneous equations which are linear and non-linear defining the behavior of each actor. It has activities production, factor markets, institution, which include household, government and the rest of the world, commodity markets and macro balances, including government balances, eternal balances or balance of payment balances and the saving-investment balances, (Lofgren et al., 2002).

Adhering to the core of the neoclassical economic theory (with number of assumptions, pertaining to technologies, behavior, and institutional factors of consumer and producer behavior) most CGE models are "consistent with micro-foundations which are the demand and supply functions contained in the models are consistent with the utility and profit maximization calculus (Bernow et al., 1998).

The neo-classical assumptions of rational agents in the demand and supply functions are the source of the major weaknesses of CGE models. Bernow et al. (1998) discussed three weakness of these assumptions as the normative implications of micro-foundations which bias model results against government intervention; the assumption of convex technologies (nonincreasing returns to scale); the aggregation over individual actors (impede an adequate representation of technological change). Technically, the result that the solutions of CGE models constitute unique Pareto-efficient resource allocations hinges on the use of micro-foundations. Bernow et al. (1998) further explained that micro-foundations come with a set of stringent assumptions which are unrealistic such as, the assumption that production technologies exhibit constant returns to scale, that firms are price takers, that economic agents act with perfect rationality, and that consumer utility functions are very similar across individuals.

There is no room in the CGE model for one sector to improve without another sector losing resource. This is because CGE models are constructed to produce a unique model solution that is "Pareto-efficient." A Pareto-efficient resource allocation (i.e., the pattern of production, investment, and consumption by the various sectors in the economy) is an allocation that leaves no room for improvement without making the other party worse off. Thus, producers or consumers cannot maximize production or utility without another adversely reducing resources from another producer or consumer. Bernow et al., 1998, have argued that Pareto-efficiency could be an appealing criterion for evaluating different states of the world since it seems value-neutral (i.e., It does not require that the welfare of one party be weighed against that of another). This "efficiency" criterion would allow a model society to make unambiguous improvements by moving between many different states of the world; every Pareto-inefficient state can thus be unambiguously improved.

"The existence of such a solution, and its uniqueness, suggests that the free market (in the model: the free play of prices, and the lack of regulation) does best: it brings about "efficiency." Government intervention "distorts" this allocation and thus carries a welfare cost. Any policy is evaluated in light of its impacts on efficiency." (Bernow et al., 1998)

However, for a developing country like Ethiopia Pareto-efficiency is a limited, theoretical criterion which is far from reality. Thus, while CGE models shed light in the overall changes of the economy it is important for policy makers to understand this weakness of the model. The market does not produce an optimal allocation, as suggested by neoclassical economic theoretical models and the rhetoric that flows from them.

As equilibrium simultaneous models, in CGE all accounts must be in equilibrium. Government balances through saving/deficit. The goods market, factor markets and foreign exchange markets clear through prices, factor prices and exchange rate prices, relatively. Each equation defines the behavior of the actors in SAM. Producers maximize profit given relative prices and consumers maximize utility given household income. For producers profit maximization takes place through an activity subject to production technology specified by constant elasticity of substitution (Leontief, linear or Cobb-Douglas functions) production function for the quantities of value-added and aggregate intermediate inputs (Breisinger et al., 2009).

The neoclassical production function is based on the view that inputs can be substituted against each other. Furthermore, it is assumed that the marginal productivities of inputs are declining (that is, the more of an input is used, the less this additional amount of input causes output to grow, all other things equal). The neoclassical production function concept distinguishes substitution between inputs, which is the movement on an isoquant, from technical progress, which is reflected in a movement of the isoquant towards the origin, reflecting the fact that a given amount of output can be produced with smaller amounts of inputs.

"Given the conventional assumptions about the shape of the production functions and a vector of input prices, there is a unique cost-minimizing combination of inputs. The choice of input mix to produce an output depends on input prices alone. If the price of an input rises, producers will choose another point on the isoquant by substituting away from this input towards the others. Producers' input demand functions follow from their cost-minimizing behavior and the shape of the production functions" (Breisinger et al., 2009).

Factor market closure chosen depends on the type of analysis required. The default closure is when the quantity supplied of each factor is fixed at the observed level and an economywide wage variable is free to vary (an activity-specific wage is fixed) to assure that the sum of demands from all activities equals the quantity supplied. Another alternative is to assume unemployment of factors prevails (factor supply varies) and real wage is fixed. Domestic output may be sold in the market or consumed at home (Breisinger et al., 2009). For commodities sold in the market, CGE model first generates aggregated domestic output from the output of different activities of a given commodity. 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, while activity-specific commodity prices serve to clear the implicit market for each disaggregated commodity. Total domestic output is allocated between exports and domestic sales on 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 markets, export demands are infinitely elastic at given world prices. The price received by domestic suppliers for exports is expressed in domestic currency and adjusted for the transaction costs (to the border) and export taxes (if any).

3.3.1. Model Closures

The debate on macro closures became popular in the late 1970s when Amartya Sen published his famous paper discussing four fundamental closures for a simple CGE model in 1963 and in the early 1980s. When the modeler closes a model, it refers to ex- ante equilibriums in different markets. For instance, it should determine how the savings investments market works, which aggregate is predetermined and which one moves to reach the equilibrium. In a closed economy, the only ex- ante equilibrium conditions to specify are the labor and the saving- investments markets. In an open economy we have to introduce a new equilibrium condition in the foreign exchange rate and to count for new sources of savings in the savings- investments balance.

In the Neoclassical closure investments are not exogenously determined but endogenous, and consequently their amount is equal to savings. The Keynesian closure allows for Unemployment. Thus, labor supply is not fixed, but endogenized. The Johansen closure is a mid-point between the Neoclassical and the Keynesian. It maintains the neoclassical setup on the production side but there is also an exogenous level of investments (as in Keynes). In this case, the fundamental mechanism works through an endogenous fiscal policy instrument. Finally, there is the Neo-Keynesian closure (in Sen's terminology, otherwise also defined Kaldorian), where an income distribution mechanism acts. the Neoclassical and the Johansen closures may be compared. Both of them assume that the production side has full utilization of available resources so that real wage and the rate of return to capital are determined. Therefore, the production side is completely separated from the demand side where the two models differ. There is no room for an interaction between the two sides. Neoclassicals suppose there is a level of investments that equals the total amount of savings that are fixed in the economy. The Johansen closure assumes exogenous investments and endogenous consumption, whose volume adjusts to liberate sufficient savings. The Keynesian possibility supposes that a supply- demand interaction determines employment level, output, and relative prices. The Kaldorian closure supposes that employment and output are fixed but income redistribution takes place and frees the necessary savings.

Table 2: A summary of the four macro closures assumptions

Equilibriums	Neoclassical	Keynesian	Johansen	Kaldorian
Factor market	Full-Employment	Unemployment	Full-Employment	Full-Employment
Savings-Investments	Saving-driven	Exogenous Investment	Exogenous investment	Exogenous Investment
Variables				
Price	Numeraire	Numeraire	Numeraire	Numeraire
Labor	Fixed		Fixed	
Capital	Fixed	Fixed	Fixed	Fixed
Investment		Fixed	Fixed	Fixed
Wage		Fixed		Fixed
Workers-Saving propensity	Fixed	Fixed		Fixed
Rent-saving propensity	Fixed	Fixed		Fixed

Source: Delpiazzo, E., 2011

The model closure in this study which are assumed appropriate for the Ethiopian Economy are as follows:

Government Balance (Fiscal balance): is the overall balance between government spending and revenue. There are three options for government budget balance closure. The first closure choice is when government saving is flexible and fixed tax rates. The second is fixed government savings and uniform direct taxes are flexible. The third choice is fixed government saving and scaled direct tax rates changes. This study chose the flexible government saving and fixed tax rates, where the budget balance adjustment is done by government through a change in tax rates.

External Balance/ Current Account Balance: is an important indicator of economies wealth. In the external account closure either follows a flexible exchange rate and fixed foreign savings or vice versa. This study uses the fixed exchange rate and flexible foreign saving closure.

Saving-investment balance: is the equilibrium between national saving and investment. This study follows Investment driven adjustment. Where the saving adjusts to ensure saving-investment balance.

Factor Market Balance: is the balance between the supply and demand of factors of production. The closure in this study assumes full employment of skilled labor, land and capital, while labor unemployment and mobility across sectors exists for semi-skilled and unskilled labor. Labor and land can be used for any activities, while capital is immobile across sectors (it is activity specific). The consumer price index (CPI) is set as the numeraire (standard), where all other prices are relative to the CPI.

Conclusion

Climate change has an economy-wide consequence. This chapter presented the research methods used in estimating and analyzing climate change consequences on international trade. The presentation of the simple econometrics models was necessary for estimating the impact of climate variables (temperature and precipitation) on agricultural factor productivity. The updated 2009/10 Ethiopian SAM produced by the Ethiopian Research Institute (EDRI) is applied as the main dataset for calibration of the CGE model.

CHAPTER FOUR: SIMULATION RESULTS AND DISCUSSIONS

4.1. INTRODUCTION

The aim of this chapter is to present along with discussions of results found the regression estimates and simulation of the CGE model. The first section presents the econometric regression results for the impact of climate variables on agricultural total factor productivity. Then the simulation results from the dynamic CGE model will be presented with a focus on impacts of climate change on exports and imports, as it is the objective of this paper. This paper presents results from a single baseline and scenario made for five years, hence, results are rather indicative.

4.2. ECONOMETRICS RESULT

The tests that were carried out to assess the statistical quality of the econometric models were: unit root test and multicollinearity tests. Time series regression model based on time series data (data collected over a period of time) using autoregressive distributed lag (ARDL) method of estimation was applied in this study. The classical ordinary least square (OLS) time series regression model is based on the assumption that the data generating process are stationary, that is, the mean and variance of the time series do not change or vary systematically over time (Gujarati 2004). However, the ARDL method of estimation does not require for all variables under study to be I(0). It does however require the variables to be I(2) (Pesaran and Shin, 1998).

ARDL test is relatively efficient for small and finite sample data sizes and obtain unbiased estimates of long-run model (Harris and Soilis, 2003). With many reductive and transformative process, the econometrics regression result is as depicted in table 3. There is a significant negative long-run relationship between temperature change (T-change) and total factor productivity. Thus, ceteris paribus with a positive temperature change agricultural TFP declines.

Table 3: Regression results

ARDL (1,1,2,2,4) regression						
Sample: 1966 - 2013					Number of obs = 48	
					R-squared = 0.8816	
					Adj R-squared = 0.8314	
Log likelihood = 85.387543					Root MSE = 0.0493	
D.TFP	**Coef.**	**Std. Err.**	**t**	**P>t**	**[95% Conf.**	**Interval]**
ADJ						
TFP						
L1.	-1.367752	.1472326	-9.29	0.000	-1.667299	-1.068206
Long-Run						
T-change	-.1821584	.0680787	-2.68	0.012	-.3206655	-.0436513
Mar-May	.1444844	.0441567	3.27	0.003	.0546469	.2343218
June-Aug	.0406739	.0464723	0.88	0.388	-.0538747	.1352225
CP	.5782221	.218827	2.64	0.012	.13301521	.023429
Short-Run						
T-change						
D1.	.1181467	.0659277	1.79	0.082	-.0159841	.2522775
Mar-May						
D1.	-.2069267	.0437925	-4.73	0.000	-.2960232	-.1178302
LD.	-.0585491	.0255971	-2.29	0.029	-.1106267	-.0064715
June-Aug						
D1.	.0526611	.0527619	1.00	0.325	-.0546838	.1600059
LD.	.0802544	.032107	2.50	0.018	.0149322	.1455767
CP						
D1.	-.7461847	.2662888	-2.80	0.008	-1.287953	-.204416
LD.	-.5649463	.2096323	-2.69	0.011	-.9914465	-.1384461
L2D.	-.4044577	.1317432	-3.07	0.004	-.6724912	-.1364241
L3D.	-.0915507	.075428	-1.21	0.233	-.2450101	.0619087
cons	-.0091909	.0162918	-0.56	0.576	-.0423369	.023955

Cp=change in precipitation

The temperature change from the season September to November as well as the summer temperature changes has a significant impact on agricultural TFP. Seasonal temperature changes affect the agricultural production as most farming systems in Ethiopia are small-scale and highly dependent on climate variables.

In the short-run the season from march to May has a significant impact on total factor productivity. The result shows that one-degree Celsius change in the season between March to May in the short-run TFP growth will decline by 0.2%.

4.3. SIMULATION RESULTS

The primary shocks in the agricultural TFP into CGE model involved a mapping of the effects with exogenous parameters of the CGE model. Ceteris paribus, climate change is regarded as exogenous technological change leading to change in agricultural TFP (Delink et al., 2017, Amsalu 2016). We shocked the technological change parameter of exportable agricultural total factor productivity of the calibrated CGE model.

Delink et al (2017), applied an ENV linkage dynamic CGE model in-order to look at the consequences of climate change on international trade on global level. They found that for regions most affected by climate change, such as India and sub-Sharan Africa, exports will contract more than GDP. Furthermore, they discussed on how import shares in these countries will rise in-order to compensate the decline in domestic production due to climate change. The obvious outcome is that climate change will have an adverse impact on the productivity and hence comparative advantage of developing countries more than those of developed countries.

Income Effect:

According to Dellink et al., (2017) countries whose national income deteriorates from climate impacts will reduce domestic economic activity as well as the volume of trade (both for imports and exports). The result from our simulation is in line with the above argument (table 4), thus, for Ethiopia quantity of economic activity as well as the volume of trade (import and export) declined as a consequence of the TFP shock introduced mainly due to climate change. The important caveat to remember is that this analysis only considers a scenario with no policy measures taken for mitigating climate change.

Table 4: Macroeconomic Impacts

Description	INITIAL	BASE	SIM
ABSORP	457.7	622.6	500.9
PRVCON	338.6	459.9	363.0
FIXINV	85.5	118.9	104.2
GOVCON	31.9	41.9	31.8
EXPORTS	**52.1**	**88.7**	**58.8**
IMPORTS	**-126.5**	**-179.7**	**-142.5**
NETITAX	28.4	42.2	35.6
GDPFC2	355	489.3	381.6

Source: Author's computation

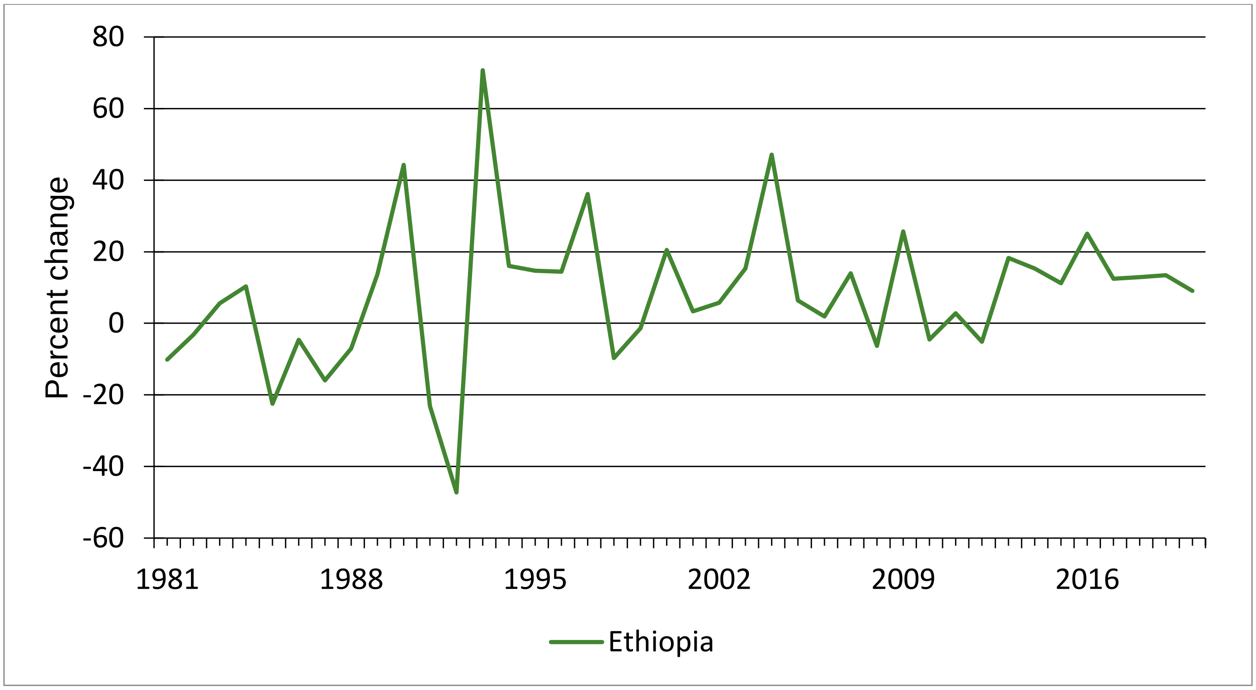
Table 5: Nominal Percentage change

Description	INITIAL	BASE	SIM
ABSORP	457.7	33.8	8.7
PRVCON	338.6	32.9	7.9
FIXINV	85.5	31.3	21.4
EXPORTS	**52.1**	**62.0**	**11.9**
IMPORTS	**-126.5**	**35.7**	**11.6**
NETITAX	28.4	30.7	9.3
GDPFC2	354.9	37.7	8.1

Source: Author's computation

The simulation result (table 5) can be compared with the available statistics of exports of goods for Ethiopia. We have found that the percentage change for exports during the simulation period (2009-2015) to be 12% approximately. The data we obtained from the IMF data portal shows percentage change of about 11.5% (Figure 14). Although beyond the scope of this study, it is advised for a thorough analysis of the volatility of Ethiopia's export sector amid climate change.

Figure 14: Volume Export (%change) for Ethiopia



Source: http://ethiopia.opendataforafrica.org/datasourceIMF

Table 6: Real Macroeconomic impacts/GDP (% Δ)

Description	INITIAL	BASE	SIM
ABSORP	457.7	6.3	1.8
PRVCON	338.6	6.3	1.4
FIXINV	85.5	6.8	4.0
EXPORTS/GDP	**52.1**	**11.2**	**2.5**
IMPORTS/GDP	**-126.5**	**7.2**	**2.4**
NETITAX	28.4	8.2	4.6
GDPFC2	354.9	6.6	1.4

Source: Author's computation

As import changes are essentially driven by income change, import reductions are very close to GDP reduction. An important role in adapting to the climate impacts is through adjustments of the real exchange rate, which adjust endogenously to correct any imbalance in trade flows. However, in the case of Ethiopia where Exchange rate is not as flexible, adjustments to climate shocks on the international trade will be complicated. This thesis strictly followed a fixed exchange rate closure for Ethiopia's economy and hence insignificant changes were observed on the exchange rate. However, when using a flexible exchange rate closure our simulation results indicated an appreciation of the exchange rate to a percentage change of -0.89 from the base scenario where percentage change is -4.81. These results are in line with the findings of Amsalu (2016), who found an appreciation of exchange rate which impacts exports adversely than imports. Appreciation of the real exchange for Ethiopia could be a possible implication of loss in its competitiveness. This could be reflecting Balassa-Samuelson effect which suggests a shift to in production to a more tradeable goods and services which in-turn rises wages for both tradeable and non-tradable sectors leading to an increase in domestic prices and thus, relative prices vis-a-vis other countries, i.e. the real exchange rate. overall Percentage change in quantity of exports for agricultural products declined.

Comparative Advantage

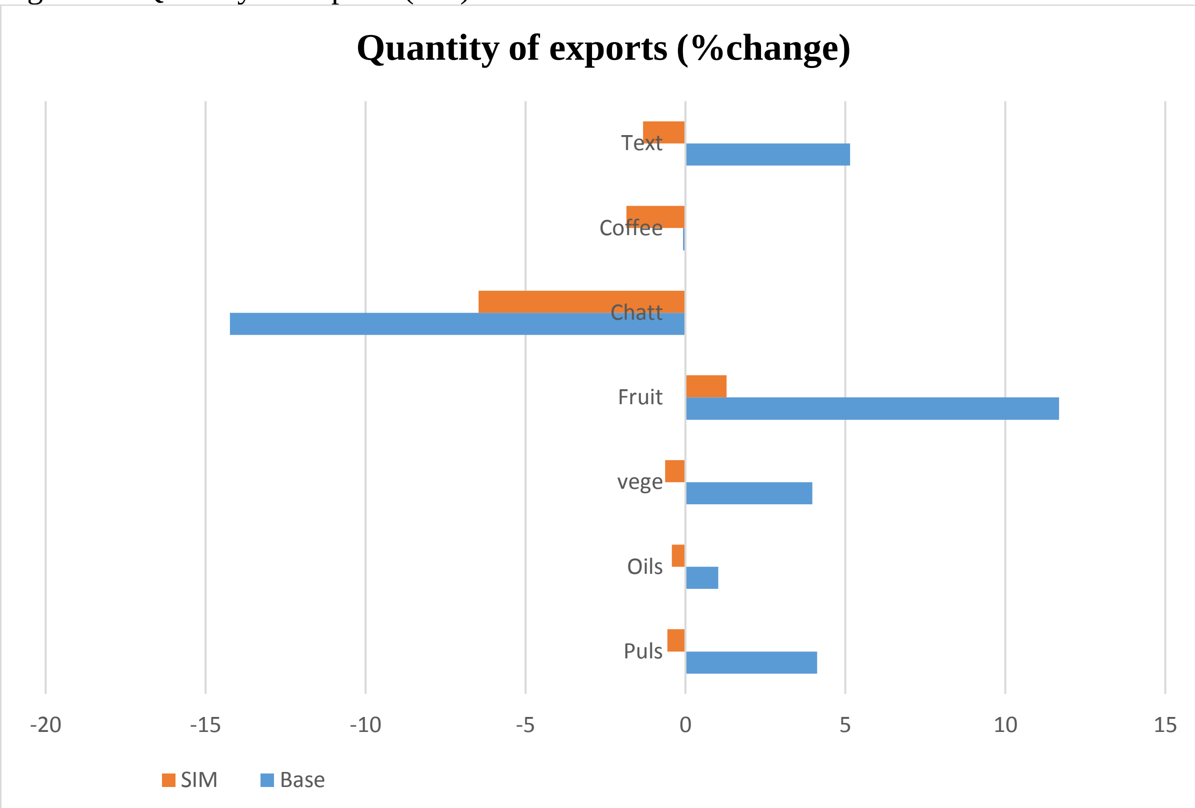
The estimates above show the economic consequences of climate change damages the income and trade flows of Ethiopia. Ethiopia has comparative advantage in agricultural products, both livestock and crop. For instance, Abtew (2015) studied the reveled comparative advantage of leather industry with selected African economies and found an estimate of approximately 3.4% (which shows high RCA for Ethiopia).

To understand the position of competitiveness Ethiopia has in the international market, it is important to first look at the climate change impacts on its major competing countries. Dellink et al. (2017) states that if impacts of climate change were identical across countries, all regions would maintain their international competitive position. Hence, differences in impacts show that relative competitive positions will change in the international market among countries. In general, country-specific climate change damages on comparative advantage could be determined by understanding the level of impact of climate change in other countries and changes in international trade patterns in own country. However, such analysis is beyond the scope of this paper and hence recommended for future studies.

With the growing population and projected economic growth of the continent demand for livestock products will increase. According to FAO (2012), both dairy and other livestock products have a high income-elasticity of demand, especially at low-income levels. This means that increases in income will lead to large increases in demand for livestock products. Thus, per capita income growth will translate into significant increases in demand for livestock products.

The agricultural sector is particularly affected by increased temperature and heat stress (Dellink et al., 2017). Agricultural production most affected as a consequence of increasing temperature overtime include' s coffee production (figure 15). The simulation result of the decline in percentage change in export is consistent with the world trade organization (WTO) statistics data which shows an annual percentage change of -6 in 2015. As coffee is one of the main exported agricultural product for Ethiopia, its decline in production will impact trade patterns as well as competitiveness in the international market. The results of this study show exports decline more than imports and GDP, which will weaken trade position Ethiopia has in the international market. This will provide the stage for least affected countries to improve their competitive position in trade. It is a plausible scenario that least affected countries, despite being negatively affected by climate damages, may increase their competitiveness given that other competitors for a certain market are more severely damaged (Dellink et al., 2017).

Figure 15: Quantity of Exports (%Δ)



Source: Author's computation

4.4. CONCLUSION

In this chapter, results from the time-series econometric estimation on the impact of climate variability on agricultural total factor productivity was presented. The estimates were based on time-series data from 1960 to 2015. After estimating of the econometric model, calibration of the computable general equilibrium model was discussed. Results and implication of results were further presented. Although a more robust analysis is suggested, the simulation of CGE model focused on one scenario. Hence, the analysis of the model is more indicative of the economic consequences (including the international trade) of climate change. The impact of climate change on comparative advantage of Ethiopia was briefly discussed from the results of the CGE model. Future studies are suggested on analysis of climate change impact on the comparative advantage with comparison of impacts of climate change on production costs for other countries**.**

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

The climate resilient green economy strategy (CRGE) of Ethiopia has been initialized since 2011, however, very few studies have shown the importance of synergies between policies of international trade and climate change. Hence, with the right trade and climate policies, GHG emissions will be reduced at the least cost. It is also imperative for a country to have a thorough analysis on the interaction between trade and climate change in order to identify its position of comparative advantage in international trade. Although a more robust modeling analysis would set a clearer picture by comparing different models and scenarios, it requires extensive data and effort. Hence, this paper only presents one plausible scenario of future developments, indicative of the plausible impacts of climate change on international trade. This paper also limits itself to studying the economic consequences of climate change damages for Ethiopia and does not include impacts on other regions for the analysis of comparative advantage (it is beyond the reach of this paper). Nonetheless, a number of general insights are worth highlighting.

The anticipation of high growth in international trade which comes along with increased economic performance for Ethiopia may be too ambitious if it ignores the negative impacts of climate change. Climate damages will put negative pressure on the economies of almost all regions, and trade flows are smaller when considering climate damages than in the baseline projections that ignores impacts of climate change on the economy (Delink et al., 2017).

Our findings from the dynamic CGE model indicate that climate change will put an adverse impact on trade flows with exports becoming more contract than GDP and imports. Ethiopia's major exports are agricultural products which makes its position in the international market of goods and services highly susceptible to climate change. Hence, shifts in comparative advantage of the country is possible in the event of climate change damages. The model results also indicated increased cost of production which will lead to increases in prices of goods and services for both tradeable and non-tradeable products. This appreciation of the exchange rate will have a weakening consequence on trade flows, particularly because Ethiopia's main exports are primary products.

The study of comparative advantage of a country requires not only analysis of own countries shifts of specialization but also the economic consequences of climate change on countries it compute with in the international market. Dellink et al. (2017) analyzed shifts in comparative advantage of OECD countries compared to other regions (the domestic damages compared with those of the main trading partners, rather than absolute damage levels). They suggested that producers in the least affected countries can improve their competitive position on both domestic and export markets. Comparative advantage tends to decline in countries where climate damages lead to relatively large reductions in export volumes, while those regions whose export price levels change least can gain in terms of export volumes. Further studies are advised for understanding Ethiopia's comparative advantage amidst climate change.

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APPENDIX I: Structure of the CGE Model

The structure of the CGE model is divided into four major blocks: prices, production and trade, institutions, and system constraints. The discussion below is based on Lofgren et al.,2002.

The price Block:

The price block consists of equations in which endogenous model prices are linked to other prices (endogenous or exogenous) and to nonprice model variables.

Import Prices of commodities (PMc):

Expressed in local currency units (LCU) is summation of price of imports (considering the exchange rate and import tariffs) and transaction costs (the cost of trade inputs needed to move the commodity from the border to the demander) per unit of the import. Mathematically:

$$\boldsymbol{PMc = pwmc\,(1 + tm).EXR + \sum . c' \varepsilon ct \quad PQc.icmc'c} \text{ .... } \textbf{Equation 3}$$

Where, C is set of commodities, pwmc is CIF (cost, insurance and freight) import in foreign currency units (FCU), tm is import tariff, EXR is exchange rate, PQc is composite of commodity price including sales tax and transaction costs, icmc'c is quantity of commodity c' as trade input per imported unit of c. In the model the variables are written in capital letters whereas parameters are written in small letters. Hence, in the model price of imported commodities (PMc) and exchange rate (EXR) are flexible and tariff rate (tm) and world price (pwmc) are fixed

Export Price:

It is price of exported commodities in the international market. Mathematically it is explained as in equation 5.

$$\boldsymbol{PEc = pwec.(1 - tec).EXR - \sum_{c'CT} PQc.icec'c} \text{.................................} \textbf{Equation 4}$$

Where PEc is price of exported commodities in LCU, pwe_c is export price (Free on Board) in FCU.

Demand Price of Domestic Non-traded Goods:

It is the prices for domestic output which is used domestically. It is the summation of the price of domestically supplied commodities and trade input costs per unit of domestic sales. Mathematically:

$$PDDc = PDSc + \Sigma c' \varepsilon CT\ PQc.icdc'c$$ ....**Equation 5**

Where PDDc is demand price for commodities produced and sold domestically, PDSc is the supply price for commodity produced and sold domestically, and icdc'c is quantity of commodity c' as trade input per unit of c produced and sold domestically.

Absorption:

It is the aggregate demand for final marketed output (imported and domestically produced) excluding commodities for export. It is the sum of the domestic output and imported commodities at demand prices. Mathematically:

$$PQc(1 - tq_c).QQc = PDDc.QDc + PMc.QM_C$$ .... **Equation 6**

Where QQc is quantity of goods supplied to domestic market, QDc is quantity sold in the domestic market, QMc is quantity imported to the domestic market and tqc is sales tax rate.

Marketed Output Value:

It is the sum of the values of domestic sales and exports. Mathematically it is represented as follows:

$$PXc.QXc = PDSc.QDc + PEc.QEc$$ ....**Equation 7**

Where PXc is aggregate producer price, QXc is aggregate marketed quantity of domestic output of commodity and QEc is quantity of exports.

Activity Price:

It is the yields per activity unit multiplied by activity-specific commodity prices, summed overall commodities. This allows for the fact that activities may produce multiple commodities.

$$\boldsymbol{PAa = \sum_{c\varepsilon C} PXACac.\theta ac} \text{.. Equation 8}$$

Where a is set of activities, PAa is price of activity, PXACc is producer price of commodity c for activity a and θ_{ac} is the yield of commodity c per unit of activity a.

Aggregate Intermediate Input Prices:

Is activity specific price which is intermediate input cost per unit of aggregate intermediate input. It is expressed mathematically as follows:

$$\boldsymbol{PINTA\mathrm{a} = \sum_{c\varepsilon C} PQc.\, ica_{ca}} \text{... Equation 9}$$

Where PINTAa is price of intermediate input for activity a, ica_{ca} is the quantity of c per unit of aggregate intermediate input a.

Production and Trade Block:

Producers in activities are assumed to maximize profit given prices of factors of production and intermediate inputs. The CGE model includes the first-order conditions for profit-maximization by producers (Lofgren et al 2002. There are two alternative production functions namely the Leontief (LEO) production function or constant elasticity of substitution (CES) function. CES allows producers to respond to changes in relative factor returns by substituting available factors till final output. For a Leontief function at the top of the technology nest:

$$\boldsymbol{QVA_{\mathrm{a}} = iva_{\ \mathrm{a}}.\, QA_{\mathrm{a}}} \text{.. Equation 10}$$

Where a ε ALEO (set of activities with Leontief function at the top of the technology nest), iva_a is quantity of value added per unit of activity.

$$\boldsymbol{QINTA_a = inta_a\ .\, QA_a} \text{.. Equation 11}$$

Where $inta_a$ is quantity of aggregate intermediate inputs per unit of activity a.

Producers decision to produce for the domestic market or for international market is determined by constant elasticity transformation (CET). The aggregate marketed domestic output is then defined as:

$$QXc = a_c^t \left\lfloor .\left(\delta c^t . QE_c^{p_c^t} + (1 - \delta_c^t) QD_c^{p_c^t}\right\rfloor^{1/p_c^t} \text{.. Equation 12}$$

Where P^t_c is CET function exponent, a_c^t is CET shift parameter, δ is CET share parameter.

$$\frac{QE_c}{QD_c} = \left[\frac{PE_c}{PDS_c} \cdot \frac{1-\delta_c^t}{\delta_c^t}\right]^{\frac{1}{p_c^t - 1}} \text{.. Equation 13}$$

Equation 13 depicts the export-domestic supply ratio, which is the first-order condition for the optimal mix of Export-domestic supply. The increase in export-domestic price ratio will lead to an increase in export-domestic supply of commodity c primarily due to the increase in revenue.

<u>The Armington function</u>

Based on the assumptions (internationally traded products are differentiated by country of origin) of Paul Armington (1969), the Armington specification represents the elasticity of substitution between differentiated products of different countries, and hence imperfect substitutability of imported and domestically produced commodities. Armington function (QQc) is a function of import quantity (QMc) and domestic output (QDc). It is represented mathematically as follows:

$$QQc = \alpha_c^q . \left[\delta_c^q . QM_c^{-p_c^q} + \left(1 - \delta_c^q\right) . QD_c^{-p_c^q}\right]^{\frac{-1}{p_c^q}} \text{.................................. Equation 14}$$

Where $\alpha_c{}^q$ is an Armington function shift parameter, $\delta_c{}^q$ is an Armington function share parameter, and $\rho_c{}^q$ an Armington function exponent. Just like the optimal mix between export-domestic supply was determined by the ratio of export-domestic supply, the optimal mix for import-domestic output is represented by the ratio of import-domestic demand which is the function of domestic-import price ratio (eq 16).

$$\frac{QM_c}{QD_c} = \left[\frac{PDD_c}{PM_c} \cdot \frac{\delta_c^q}{1-\delta_c^q}\right]^{\frac{1}{1+\rho^q}} \text{.. Equation 15}$$

Institutional Block

The institutional block is composed of the institutions of a given economy such as households, governments, and the rest of the world. This includes factor payments, institutional factor income, income for non-government institutions, household's consumption expenditures, investment demand, government consumption demand, government revenue and government expenditure.

Factor payments defines the total income of each factors (YF_f), technically it is the total of activity specified factor income multiplied by employment level.

$$YF_f = \sum_{a \varepsilon A} WF_f \, . \, \overline{WFDIST}_{fa} . QF_{fa} \text{.. Equation 16}$$

Where YF_f is factor incomes. WF_f is the average factor price, the fixed term $WFDIST_{fa}$ represents the wage distortion factor (which measures the deviation from the average wage) and QF_{fa} is the quantity demanded for factor f for activity a. The factor income is then divided among domestic institutions in fixed shares after payments of direct factor taxes and transfers to the rest of the world (equation 18).

$$YIF_{if} = shif_{if} \, . \left[(1 - tf_f)YF_f - trnsfr_{rowf} . EXR\right] \text{.................... Equation 17}$$

Where i (set of institutions both foreign and domestic) is the element of INSD (set of domestic institutions), YIF_{if} is income to domestic institutions i from factor f, $shif_{if}$ share of domestic institution in income of factor f, tf_f direct tax rate for factor f, and $trnsfr_{rowf}$ transfer from factor f to rest of the world.

Investment demand is quantity demanded for a base year multiplied by adjustment factors. Mathematically it is defined as the follows:

$$\mathbf{QINV_c = \overline{IADJ}.\,\overline{qinv_C}}$$ ……………………………………………………………………**Equation 18**

Where QINVc is quantity of fixed investment demand for commodity c, IADJ is the investment adjustment factor (exogenous variable), and qinvc is the base-year quantity of fixed investment demand.

.

APPENDIX II: GAMs CODES

```
*NUMERAIRE ------------------------
IF(NUMERAIRE(SIMCUR)……………………………………………………….. EQ 1,
 CPI.FX     = CPI0;
 DPI.LO     = -INF;
 DPI.UP     = +INF;
 DPI.L      = DPI0;  );
IF(NUMERAIRE(SIMCUR)………………………………………………………… EQ 2,
 DPI.FX     = DPI0;
 CPI.LO     = -INF;
 CPI.UP     = +INF;
 CPI.L      = CPI0;  );
IF(NUMERAIRE(SIMCUR) ……………………………………………………….EQ 3,
 DPI.LO     = -INF;
 DPI.UP     = +INF;
 DPI.L      = DPI0;
 CPI.LO     = -INF;
 CPI.UP     = +INF;
 CPI.L      = CPI0;  );
*GOVERNMENT ----------------------
IF(GOVCLOS(SIMCUR) …………………………………………………………….EQ 1,
 TINSADJ.FX = TINSADJ0;
 DTINS.FX   = DTINS0  ;
 TQADJ.FX   = TQADJ0;
 DTQ.FX     = DTQ0;
 GSAV.LO    = -INF    ; GSAV.UP   = +INF; GSAV.L   = GSAV0;
 );
IF(GOVCLOS(SIMCUR)…………………………………………………………….. EQ 2,
 TINSADJ.FX = TINSADJ0;
 DTINS.LO   = -INF    ; DTINS.UP  = +INF; DTINS.L  = DTINS0;
 TQADJ.FX   = TQADJ0;
 DTQ.FX     = DTQ0;
 GSAV.FX    = GSAVSIM(SIMCUR,YRCUR);
 );
IF(GOVCLOS(SIMCUR)…………………………………………………………… EQ 3,
 TINSADJ.LO = -INF   ; TINSADJ.UP = +INF; TINSADJ.L = TINSADJ0;
 DTINS.FX   = DTINS0 ;
 TQADJ.FX   = TQADJ0;
 DTQ.FX     = DTQ0;
```

```
 GSAV.FX    = GSAVSIM(SIMCUR,YRCUR);
 GSAV.FX$YR1(YRCUR) = GSAV0;
 );
IF(GOVCLOS(SIMCUR)…………………………………………………………………… EQ 4,
 TINSADJ.FX = TINSADJ0;
 DTINS.FX   = DTINS0 ;
 TQADJ.FX   = TQADJ0;
 DTQ.LO     = -INF;   DTQ.UP = +INF; DTQ.L = DTQ0;
 GSAV.FX    = GSAVSIM(SIMCUR,YRCUR);
 );
IF(GOVCLOS(SIMCUR)…………………………………………………………………… EQ 5,
 TINSADJ.FX = TINSADJ0;
 DTINS.FX   = DTINS0 ;
 TQADJ.LO   = -INF; TQADJ.UP = +INF; TQADJ.L = TQADJ0;
 DTQ.FX     = DTQ0;
 GSAV.FX    = GSAVSIM(SIMCUR,YRCUR);
 );
IF(GOVCLOS(SIMCUR)…………………………………………………………………… EQ 6,
 TINSADJ.FX = TINSADJ0;
 DTINS.FX   = DTINS0 ;
 TQADJ.FX   = TQADJ0;
 DTQ.FX     = DTQ0;
 GSAV.FX    = GSAVSIM(SIMCUR,YRCUR); );

*CURRENT ACCOUNT -----------------
IF(ROWCLOS(SIMCUR)…………………………………………………………………… EQ 1,
 FSAV.FX    = FSAVSIM(SIMCUR,YRCUR);
 EXR.LO     = -INF; EXR.UP  = +INF; EXR.L   = EXR0;
 );
IF(ROWCLOS(SIMCUR)……………………………………………………………………. EQ 2,
 EXR.FX     = EXRSIM(SIMCUR,YRCUR);
 FSAV.LO    = -INF; FSAV.UP = +INF; FSAV.L = FSAV0;
 );
IF(ROWCLOS(SIMCUR)……………………………………………………………………. EQ 3,
 EXR.FX     = EXRSIM(SIMCUR,YRCUR);
 FSAV.FX    = FSAVSIM(SIMCUR,YRCUR);
 );
```

***SAVINGS AND INVESTMENT ---------**

```
IF(SICLOS(SIMCUR)……………………………………………………………………… EQ 1,
 MPSADJ.FX  = MPSADJ0;
 DMPS.LO    = -INF; DMPS.UP = +INF; DMPS.L = DMPS0;
 IADJ.FX    = IADJ0;
 INVSHR.LO  = -INF; INVSHR.UP = +INF; INVSHR.L = INVSHR0;

*-------
 MGADJ.FX$YR1(YRCUR) = MGADJ0;
 MGADJ.FX$(NOT YR1(YRCUR)) = MGADJ.L * (1 + QGGR2(SIMCUR,YRCUR));
 GADJ.FX(GOVF) = GADJ0(GOVF);

*-------
MGOVSHR.LO  = -INF; MGOVSHR.UP = +INF; MGOVSHR.L = MGOVSHR0;
GOVSHR.LO(GOVF)     =    -INF;   GOVSHR.UP(GOVF)   =   +INF;   GOVSHR.L(GOVF)   =
GOVSHR0(GOVF); );

IF(SICLOS(SIMCUR)………………………………………………………………………. EQ 2,
 MPSADJ.LO  = -INF; MPSADJ.UP = +INF; MPSADJ.L = MPSADJ0;
 DMPS.FX    = DMPS0;
 IADJ.FX    = IADJ0;
 INVSHR.LO  = -INF; INVSHR.UP = +INF; INVSHR.L = INVSHR0;

*-------
 MGADJ.FX$YR1(YRCUR) = MGADJ0;
 MGADJ.FX$(NOT YR1(YRCUR)) = MGADJ.L * (1 + QGGR2(SIMCUR,YRCUR));
 GADJ.FX(GOVF) = GADJ0(GOVF);

*-------
MGOVSHR.LO  = -INF; MGOVSHR.UP = +INF; MGOVSHR.L = MGOVSHR0;
GOVSHR.LO(GOVF)     =    -INF;   GOVSHR.UP(GOVF)   =   +INF;   GOVSHR.L(GOVF)   =
GOVSHR0(GOVF); );

IF(SICLOS(SIMCUR)………………………………………………………………………. EQ 3,
 MPSADJ.FX  = MPSADJ0;
 DMPS.FX    = DMPS0;
 IADJ.LO    = -INF; IADJ.UP = +INF;  IADJ.L = IADJ0;
 INVSHR.LO  = -INF; INVSHR.UP = +INF; INVSHR.L = INVSHR0;

*-------
```

```
 MGADJ.FX$YR1(YRCUR) = MGADJ0;
 MGADJ.FX$(NOT YR1(YRCUR)) = MGADJ.L * (1 + QGGR2(SIMCUR,YRCUR));
 MGOVSHR.LO  = -INF; MGOVSHR.UP = +INF; MGOVSHR.L = MGOVSHR0;




*-------
GADJ.FX(GOVF) = GADJ0(GOVF);
GOVSHR.LO(GOVF) = -INF; GOVSHR.UP(GOVF) = +INF; GOVSHR.L(GOVF) =
GOVSHR0(GOVF); )
IF(SICLOS(SIMCUR)………………………………………………………………… EQ 4,
 MPSADJ.FX  = MPSADJ0;
 DMPS.LO    = -INF; DMPS.UP = +INF; DMPS.L = DMPS0;
 IADJ.LO    = -INF; IADJ.UP = +INF;  IADJ.L = IADJ0;
 INVSHR.FX  = INVSHR0;

*-------
 MGADJ.LO    = -INF; MGADJ.UP = +INF;  MGADJ.L = MGADJ0;
 MGOVSHR.FX  = MGOVSHR0;

*-------
GADJ.FX(GOVF) = GADJ0(GOVF);
GOVSHR.LO(GOVF) = -INF; GOVSHR.UP(GOVF) = +INF; GOVSHR.L(GOVF) =
GOVSHR0(GOVF); );

IF(SICLOS(SIMCUR)………………………………………………………………… EQ 5,
 MPSADJ.LO  = -INF; MPSADJ.UP = +INF; MPSADJ.L = MPSADJ0;
 DMPS.FX    = DMPS0;
 IADJ.LO    = -INF; IADJ.UP = +INF;  IADJ.L = IADJ0;
 INVSHR.FX  = INVSHR0;

*-------
 MGADJ.LO    = -INF; MGADJ.UP = +INF;  MGADJ.L = MGADJ0;
 MGOVSHR.FX  = MGOVSHR0;

*-------
 GADJ.FX(GOVF) = GADJ0(GOVF);
 GOVSHR.LO(GOVF) = -INF; GOVSHR.UP(GOVF) = +INF; GOVSHR.L(GOVF) =
GOVSHR0(GOVF););
```

```
IF(SICLOS(SIMCUR)…………………………………………………………………… EQ 6,
MPSADJ.FX  = MPSADJ0;
DMPS.FX    = DMPS0;
IADJ.LO    = -INF; IADJ.UP = +INF;  IADJ.L = IADJ0;
INVSHR.LO  = -INF; INVSHR.UP = +INF; INVSHR.L = INVSHR0;

*  OPTION 1
MGADJ.FX$YR1(YRCUR) = MGADJ0;
GADJ.LO(GOVF)$FIXGOVSHR(GOVF)   = -INF;
GADJ.UP(GOVF)$FIXGOVSHR(GOVF)   = +INF;
GADJ.L(GOVF)$FIXGOVSHR(GOVF)    = GADJ0(GOVF);
GOVSHR.FX(GOVF)$FIXGOVSHR(GOVF) = GOVSHR0(GOVF);
MGOVSHR.FX  = MGOVSHR0;
*  OPTION 2
MGADJ.FX$YR1(YRCUR) = MGADJ0;
GADJ.FX(GOVF)$(YR1(YRCUR) AND (NOT FIXGOVSHR(GOVF)))       = GADJ0(GOVF);
GADJ.FX(GOVF)$((NOT YR1(YRCUR)) AND (NOT FIXGOVSHR(GOVF))) =
GADJ.L(GOVF) * (1 + QGGR(GOVF,SIMCUR,YRCUR));
GOVSHR.LO(GOVF)$(NOT FIXGOVSHR(GOVF))                    = -INF;
GOVSHR.UP(GOVF)$(NOT FIXGOVSHR(GOVF))                    = +INF;
GOVSHR.L(GOVF)$(NOT FIXGOVSHR(GOVF))                     = GOVSHR0(GOVF);
MGOVSHR.LO  = -INF; MGOVSHR.UP  = +INF; MGOVSHR.L  = MGOVSHR0;
);

IF(SICLOS(SIMCUR) ……………………………………………………………………….EQ 7,
MPSADJ.LO  = -INF; MPSADJ.UP = +INF; MPSADJ.L = MPSADJ0;
DMPS.FX    = DMPS0;
IADJ.LO    = -INF; IADJ.UP = +INF;  IADJ.L = IADJ0;
INVSHR.FX  = INVSHR0;
MGADJ.LO    = -INF; MGADJ.UP = +INF;  MGADJ.L = MGADJ0;
MGOVSHR.LO  = -INF; MGOVSHR.UP = +INF; MGOVSHR.L = MGOVSHR0;
GADJ.FX(GOVF) = GADJ0(GOVF);
GOVSHR.LO(GOVF) = -INF; GOVSHR.UP(GOVF) = +INF; GOVSHR.L(GOVF) =
GOVSHR0(GOVF);
);

IF(SICLOS(SIMCUR)…………………………………………………………………… EQ 8,
MPSADJ.FX  = MPSADJ0;
DMPS.FX    = DMPS0;
```

```
 IADJ.LO    = -INF; IADJ.UP = +INF;  IADJ.L = IADJ0;
 INVSHR.LO  = -INF; INVSHR.UP = +INF; INVSHR.L = INVSHR0;
 INVGDPSHR.LO  = -INF; INVGDPSHR.UP = +INF; INVGDPSHR.L = INVSHR0;

*-------
 MGADJ.LO    = -INF; MGADJ.UP = +INF;  MGADJ.L = MGADJ0;
* MGADJ.FX$YR1(YRCUR) = MGADJ0;
* MGADJ.FX$(NOT YR1(YRCUR)) = MGADJ.L * (1 + QGGR2(SIMCUR,YRCUR));
 GADJ.FX(GOVF) = GADJ0(GOVF);

*-------
 MGOVSHR.LO  = -INF; MGOVSHR.UP = +INF; MGOVSHR.L = MGOVSHR0;
* MGOVSHR.FX = MGOVSHR0;
* GOVGDPSHR.LO  = -INF; GOVGDPSHR.UP = +INF; GOVGDPSHR.L = GOVGDPSHR0;
 GOVGDPSHR.FX = GOVGDPSHR0;
 GOVSHR.LO(GOVF) = -INF; GOVSHR.UP(GOVF) = +INF; GOVSHR.L(GOVF) =
GOVSHR0(GOVF); );
```

***FACTOR MARKETS ------------------**

```
*Reset current definition of upward-sloping factor supply factors
 FLS(FLAB) = FLSSIM(FLAB,SIMCUR) ;

*Turn off upward sloping labor supply if present (OXYMORON CLOSURE CHOICE!)
 FLS(F)$FACTFE(F,SIMCUR)  = NO ;

*Update convergence between relative wages (see 2dsim.dat and 1dmod.dat)
 CONVERGE(F)$LREL(F) = CONVERGE(F) + WFCONV(F,YRCUR);
 CONVERGE(F)$(LREL(F) AND YR1(YRCUR)) = CONVERGE0(F);)

* Factor markets. Start by updating sectoral and aggregate labor supply levels
* using values set in 1simulation.dat. Note that initial year level is set to
* QF0.L in 1simulation.dat. Set sectoral allocation by simple proportionate growth.
* Capital stock factors (FCAP) have already been set above. Only FLAB and FCAP
* factors are updated. All others remain as in base solution.

* QF.L(F,A)$((NOT AFX(A)) AND (NOT YR1(YRCUR)) AND (NOT FAGG(F)) AND (NOT
FCAP(F)) AND (NOT SLFGR(F,A,SIMCUR,YRCUR)))
* = QF.L(F,A)*(1+LFGR(F,SIMCUR,YRCUR));
```

```
* QF.L(F,A)$((NOT AFX(A)) AND (NOT YR1(YRCUR)) AND (NOT FAGG(F)) AND (NOT FCAP(F)) AND SLFGR(F,A,SIMCUR,YRCUR))

*        = QF.L(F,A)*(1+SLFGR(F,A,SIMCUR,YRCUR));

 QF.L(F,A)$((NOT YR1(YRCUR)) AND (NOT FAGG(F)) AND (NOT FCAP(F)) AND (NOT SLFGR(F,A,SIMCUR,YRCUR)))
        = QF.L(F,A)*(1+LFGR(F,SIMCUR,YRCUR));

 QF.L(F,A)$((NOT YR1(YRCUR)) AND (NOT FAGG(F)) AND (NOT FCAP(F)) AND SLFGR(F,A,SIMCUR,YRCUR))
        = QF.L(F,A)*(1+SLFGR(F,A,SIMCUR,YRCUR));

 QF.L(F,A)$(YR1(YRCUR) AND (NOT FAGG(F)) AND (NOT FCAP(F))) = QF0(F,A);


 QFS.L(FLAB) = QFS.L(FLAB)*(1+LFGR(FLAB,SIMCUR,YRCUR));
* QFS.L(FLND) = QFS.L(FLND)*(1+LFGR(FLND,SIMCUR,YRCUR));
  QFS.L(FLND)$(NOT FCAP(FLND)) = SUM(A, QF.L(FLND,A));
* QFS.L(F)$(NOT FCAP(F)) = SUM(A, QF.L(F,A));
*For factors with FMOBFE(F,SIMCUR) > 0
*Factors in FMOBFE are fully employed and mobile between activities.
*WF(F) is the market-clearing variable each factor.

LOOP(F$(FMOBFE(F,SIMCUR) AND (NOT FAGG(F))),
 QFS0(F)$FLS(F)  = QFS.L(F);
 WF0(F)$FLS(F)   = WF.L(F);
 QFS.LO(F)$FLS(F)  = -INF ;
 QFS.UP(F)$FLS(F)  = +INF ;
 WFDIST.FX(F,ANFX)       = WFDIST0(F,ANFX);
 QFS.FX(F)$(NOT FLS(F))  = QFS.L(F);
 WF.LO(F) = -INF;
 WF.UP(F) = +INF;
 QF.LO(F,ANFX)$QF0(F,ANFX) = -INF;
 QF.UP(F,ANFX)$QF0(F,ANFX) = +INF;);

*For factors with FACTFE(F,SIMCUR) > 0
*Factors in FACTFE are fully employed and activity-specific.
*WFDIST(F,A) is the clearing variable, one for each segment of the
*factor market.
```

```
*Updated values of sectoral capital and labor have been set above.

LOOP(F$(FACTFE(F,SIMCUR) AND (NOT FAGG(F))),
 WF.FX(F)      = WF0(F);
 QF.FX(F,A) = QF.L(F,A);
 WFDIST.LO(F,A)$QF0(F,A) = -INF;
 WFDIST.UP(F,A)$QF0(F,A) = +INF;
 QFS.LO(F) = -INF;
 QFS.UP(F) = +INF;);
*For factors with FMOBUE(F,SIMCUR) > 0
*Factors in FMOBUE are unemployed and mobile. For each activity, the
*wage, WFDIST(F,A)*WF(F), is fixed. QFS(F) is the market-clearing
*variable for the unified labor market.
LOOP(F$(FMOBUE(F,SIMCUR) AND (NOT FAGG(F))),
 WFDIST.FX(F,A) = WFDIST0(F,A);
 WF.LO(F) = -INF;
 WF.UP(F) = +INF;
 WF.FX(F) = WF0(F);
* WFREAL.FX(F)$(NOT LREL(F)) = WFREAL.L(F)*(1 + RWFGR(F,SIMCUR,YRCUR));
* WFREAL.FX(F)$((NOT LREL(F)) AND YR1(YRCUR)) = WFREAL0(F);
 QF.LO(F,A)$QF0(F,A) = -INF;
 QF.UP(F,A)$QF0(F,A) = +INF;
 QFS.LO(F) = -INF;
 QFS.UP(F) = +INF;);
LOOP(F$FAGG(F),
 QFS.LO(F)  = -INF ;
 QFS.UP(F)  = +INF ;
 WF.LO(F) = -INF;
 WF.UP(F) = +INF;
 QF.LO(F,A)$QF0(F,A) = -INF;
 QF.UP(F,A)$QF0(F,A) = +INF;
 WFDIST.LO(F,A) = -INF;
 WFDIST.UP(F,A) = +INF;
 WFREAL.LO(F) = -INF;
 WFREAL.UP(F) = +INF;);


*Fixing factor demands in sectors with fixed output growth
LOOP(AFX,
 QF.FX(FCAP,AFX)$(NOT FAGG(FCAP))     = QF.L(FCAP,AFX);
```

```
 WFDIST.LO(FCAP,AFX)$(NOT FAGG(FCAP)) = -INF;
 WFDIST.UP(FCAP,AFX)$(NOT FAGG(FCAP)) = +INF;
 WFDIST.L(FCAP,AFX)$(NOT FAGG(FCAP))  = WFDIST0(FCAP,AFX););

 LOOP(FIXLAND,
 QF.FX(FLND,FIXLAND)$(NOT FAGG(FLND))     = QF.L(FLND,FIXLAND);
 WFDIST.LO(FLND,FIXLAND)$(NOT FAGG(FLND)) = -INF;
 WFDIST.UP(FLND,FIXLAND)$(NOT FAGG(FLND)) = +INF;
 WFDIST.L(FLND,FIXLAND)$(NOT FAGG(FLND))  = WFDIST0(FLND,FIXLAND);

QF.FX(FLAB,FIXLAND)$(NOT FAGG(FLAB))     = QF.L(FLAB,FIXLAND);
WFDIST.LO(FLAB,FIXLAND)$(NOT FAGG(FLAB)) = -INF;
WFDIST.UP(FLAB,FIXLAND)$(NOT FAGG(FLAB)) = +INF;
WFDIST.L(FLAB,FIXLAND)$(NOT FAGG(FLAB))  = WFDIST.L(FLAB,FIXLAND) ;);
LOOP(FIXSECT,
QF.FX(F,FIXSECT)$(NOT FAGG(F))     = QF.L(F,FIXSECT);
WFDIST.LO(F,FIXSECT)$(NOT FAGG(F)) = -INF;
WFDIST.UP(F,FIXSECT)$(NOT FAGG(F)) = +INF;
WFDIST.L(F,FIXSECT)$(NOT FAGG(F))  = WFDIST.L(F,FIXSECT););
*Fixing value-added in calibrated sectors, flexing productivity adjustment
LOOP (A$(ACAL(A,SIMCUR,YRCUR) EQ 1),
QVAADJ.FX(A)$(NOT YR1(YRCUR)) = PROD(YRCURP$(ORD(YRCURP) LE
ORD(YRCUR)),1+ACALGR(A,SIMCUR,YRCURP));
QVAADJ.FX(A)$YR1(YRCUR)      = 1;
ALPHAVAADJ.LO(A)             = -INF;
ALPHAVAADJ.UP(A)             = +INF;
);

LOOP (A$(ACAL(A,SIMCUR,YRCUR) EQ 0),
ALPHAVAADJ.FX(A) = ALPHAVAADJX(A,'BASE',YRCUR);
QVAADJ.LO(A)     = -INF;
QVAADJ.UP(A)     = +INF;);

*SOLVING MODEL ---------------------------------------------------------

IF(SIMMCP(SIMCUR),
SOLVE STANDCGE USING MCP;
ELSE
SOLVE NLPCGE MINIMIZING WALRASSQR USING NLP;);
```

APPENDIX III: Data used for ARDL Estimation

Year	TFP Growth rate (%)	Tchange(^{0}C)	P (mm)	Dec-Feb	Mar-may	June -Aug	Sep-Nov	Temperature
1961	-	0.091	88.35	0.599	0.12	-0.17	-0.18	22.09
1962	0.002	-0.007	67.044	-0.36	0.23	0.15	-0.05	22.13
1963	-0.001	0.262	74.21	0.49	-0.09	0.28	0.36	22.40
1964	0.010	-0.206	77.55	-0.00	0.10	-0.43	-0.48	21.90
1965	-0.015	-0.242	61.99	-0.63	-0.25	0.02	-0.11	22.16
1966	-0.031	0.193	69.49	0.018	0.09	0.45	0.20	22.37
1967	-0.009	-0.242	93.63	0.16	-0.37	-0.31	-0.43	21.96
1968	-0.020	-0.297	76.11	-0.47	-0.75	-0.17	0.21	21.94
1969	0.000	0.296	63.23	0.12	0.32	0.28	0.44	22.65
1970	-0.003	0.328	70.78	0.69	0.36	0.31	-0.05	22.59
1971	-0.075	-0.381	68.65	-0.59	-0.41	-0.05	-0.45	22.06
1972	0.024	-0.049	70.50	-0.55	-0.08	0.28	0.15	22.49
1973	-0.018	0.39	64.06	0.32	0.75	0.36	0.11	22.84
1974	-0.023	-0.216	66.13	-0.35	-0.26	-0.04	-0.19	22.21
1975	-0.026	-0.09	75.68	-0.12	0.07	-0.15	-0.15	22.40
1976	0.076	-0.018	76.35	-0.14	-0.13	0.09	0.11	22.71
1977	0.015	0.151	76.58	0.15	-0.14	0.53	0.05	22.71
1978	-0.023	0.072	63.76	0.07	0.26	0.10	-0.15	22.66
1979	0.059	0.296	61.90	0.21	0.16	0.48	0.31	22.80
1980	0.053	0.563	61.90	0.26	0.79	0.76	0.43	23.21
1981	-0.018	0.232	55.16	0.34	-0.01	0.56	0.02	22.58
1982	-0.002	0.018	65.83	0.095	-0.26	0.38	-0.14	22.53
1983	0.017	0.186	75.32	-0.41	-0.01	0.82	0.35	22.79
1984	-0.058	0.337	70.13	-0.14	0.60	0.70	0.18	22.57
1985	-0.034	0.201	51.88	0.21	0.10	0.27	0.21	22.45
1986	0.017	0.175	68.55	0.24	0.03	0.30	0.11	22.65
1987	-0.042	0.458	57.94	0.13	-0.04	0.80	0.93	22.95
1988	0.011	0.454	58.47	0.6	0.85	0.37	-0.02	22.75
1989	-0.001	-0.062	66.81	-0.67	-0.51	0.47	0.47	22.24
1990	-0.255	0.64	68.66	0.03	0.23	1.24	1.05	22.73
1991	0.298	0.516	59.49	1.13	0.31	0.29	0.32	22.76
1992	-0.086	-0.407	63.79	-1.74	0.02	0.03	0.05	22.38
1993	-0.069	0.33	61.02	0.13	0.03	0.58	0.57	22.02
1994	-0.016	0.431	65.98	0.14	0.73	0.63	0.20	22.46
1995	0.033	0.77	68.09	0.53	0.58	0.87	1.08	23.00

1996	0.058	0.864	59.29	1.43	0.78	0.58	0.66	22.87
1997	0.015	0.73	66.98	0.64	0.4	1.08	0.81	22.79
1998	-0.076	1.20	70.59	1.38	1.37	1.54	0.52	23.07
1999	0.025	0.36	71.53	0.36	0.76	0.33	0.01	22.54
2000	0.035	0.62	60.18	0.16	0.76	0.93	0.64	22.85
2001	-0.025	0.76	74.07	0.57	0.79	0.72	0.97	22.93
2002	0.115	1.19	63.94	0.91	1.35	1.51	1.00	23.30
2003	0.046	1.20	55.19	1.30	1.39	1.13	0.97	23.24
2004	-0.060	1.01	61.47	1.01	1.07	1.25	0.71	23.13
2005	0.052	1.14	65.76	1.21	1.25	1.16	0.92	23.09
2006	0.038	1.002	68.25	1.11	0.90	1.07	0.91	23.12
2007	-0.031	0.807	70.52	0.70	0.92	0.78	0.81	23.02
2008	0.023	0.73	68.69	0.68	0.53	0.88	0.83	22.79
2009	0.019	1.28	68.96	0.91	1.33	1.58	1.29	23.58
2010	0.075	1.17	60.69	1.27	1.54	0.79	1.10	23.28
2011	-0.016	1.19	71.65	0.61	1.37	1.50	1.27	22.80
2012	0.010	0.96	66.0	0.61	1.20	0.85	1.18	23.17
2013	0.008	1.18	70.84	1.39	1.34	0.88	1.12	23.21
2014	0.022	1.03	80.62	0.78	0.90	1.28	1.16	23.22
2015	-	1.59	73.76	0.88	1.44	2.147	1.89	23.71
2016	-	1.44	.	1.50	1.72	1.269	1.27	-

Where: Tchange(^{0}C) = Change in temperature

TFP Growth rate (%) = Agricultural total factor productivity

P (mm) = Precipitation