Analyzing Economy Wide-Impact of Technological Shock on Agricultural Sector in Ethiopia Using DCGE Model: Evidence from Panel Data Analysis

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This is to certify that the thesis prepared by **Dagmawe Menelek Asfaw**, entitled: *Analysis Economy -Wide Impact of Technological Shock on Agricultural Sector in Ethiopia: A Recursive Dynamic Computable General Equilibrium Approach. Evidenced from Panel Data Analysis* and submitted in partial fulfilment of the requirements for the Degree of Masters of Science in Economics (International Economics) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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ABSTRACT

Analysis Economy Wide Impact of Technological Shock on Agricultural Sector: A Recursive Dynamic Computable General Equilibrium Model.

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This study tries to address the economy wide impact of technological shock on agricultural sector. In doing so, we employ a Sequential Dynamic Computable General Equilibrium Model. We also used econometric model i.e. panel data analysis to estimate the value of agricultural TFP of Ethiopia. For these purpose, we utilized the data of 2009/10 SAM of EDRI (Ethiopian Development Research Institute), different years of agricultural sample surveys of CSA, ministry of agriculture, WB, IMF and UNCTAD data. The estimation results panel data of this study shows that fertilizer usage, research & development, farmer training & extension have positive impact on agricultural TFP. But pesticide, irrigation and trade openness have negative impact on agricultural TFP. Despite the fact, in order to investigate the economy wide impact of agricultural TFP (technology) shock, three simulations were made turn by turn, which is induced agricultural TFP by 2.8%(simulation-1), 4.7%(simulation-2) and 5.7%(simulation-3). The results of all simulations were shows a considerable improvement on over all macroeconomics variables, sectorial performance, households income& expenditure, factor income and finally on the welfare of the households. At the end of the day to achieve the above results the paper were recommended the government and policy maker:- first the government gives more emphasis to enhancing agricultural total factor productivity; second, government give a special attention for determinants that driving agricultural total factor productivity (i.e. fertilizer usage, research & development, farmer training & extension) and finally, increasing the productivity of agricultural sector through improving TFP (technology) were prime and better mechanism rather than capital accumulation or land expansion.

Key words: - Agricultural TFP (technology), research & development, Dynamic CGE, Ethiopia

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“Great is the LORD, and greatly to be praised; and His greatness is unsearchable” Psalm 145:3

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ACRONYMS

ADLI	agricultural development led industrialization
AEZs	Agricultural Economical, Zones
AgTFP	Agricultural Total Factor Productivity
CES	Constant Elasticity of Substitution
CET	Constant Elasticity of Technology
CSA	Central Statistical Authority
DAP	Di-Ammonium phosphate
DCGE	Dynamic Computable General Equilibrium
DCs	Developed countries
EAP	Economically active person
EDRI	Ethiopian Development Research Institute
EPRDF	Ethiopian People's Revolutionary Democratic Front
ESSP	Ethiopia Strategy Support Program
EV	Equivalent Variation
GAMS	General Algebraic Modeling Systems
GDP	Gross Domestic Product
GTAP	Global Trade Analysis Project
GTPI	First Growth and Transformation Plan
GTPII	Second Growth and Transformation Plan
HCES	Household Consumption Expenditure Survey
HICES	Household Income and Consumption Expenditure Survey
IFPRI	International Food Policy Research Institute
LDCs	least developed countries
MDGs	Millennium Development Goals
MEDaC	Ministry of Economic Development and Cooperation
MoFEC	Ministry of Finance and Economic Cooperation
MOFED	Ministry of Finance and Economic Development
OECD	Organization for Economic Co-Operation and Development
PASDEP	Plan for Accelerated and Sustained Development to End Poverty
PFP	Partial factor productivity
R&D	Research and Development
ROW	Rest of the World
SAM	Social Accounting Matrix

CHAPTER ONE: - INTRODUCTION

1.1. Background

Wikipedia states that the term "**technology**" is the collection of techniques, skills, methods, and processes which humans collectively possess regarding how to produce goods and services in more efficient ways or in the accomplishment of objectives without further increment in the quantity of inputs. In business dictionary **technology** (which is a proxy of Total Factor Productivity (**TFP**[1]) in these study) is defined as a complete set of knowledge about how to produce in any economy at a point in time, including a techniques of production that are available, alternatively technology is the purposeful application of information in the design, production, and utilization of goods and service, and in the organization of human activity. A technology (TFP) shock is when there is a sudden change in technology to either benefit (positive shock which is increasing the output for a given set of inputs) or worsen (a negative shock which is decreasing the output for a given set of inputs) economic activity. In economics, a positive technological (TFP) shock is an increase in the efficiency of inputs of production (labor and capital) or process that results in an increase in output, without an increase in input. Example of Technological (TFP) shock:- development of new products or production techniques; introduction of new management techniques; changes in the quality of capital or labor; changes in the availability of raw materials or energy; unusually good or bad weather; changes in government regulations affecting production (Andrews B. et al, 2008).

The agricultural output growth is usually due to three types of factors: labor growth, capital (land) and TFP (technology). And also there are two source of growth a) input driven, which induces a growth by adding more and more quantity of inputs (like labor, land, capital, livestock) into the production and b) technology driven, which induces output growth by improvement in total factor productivity (technology) without additional increment in the usage of factor inputs (like labor, land, capital….) or otherwise known as, 'Solow residual' is the growth in real value added after deducting the contributions made by the growth of labor, land and capital (Acemoglu, 2007). Since the input driven source of growth is subject to the law of diminishing returns output growth can't be sustained indefinitely because when we increase more and more inputs with a fixed amount of

[1] Total Factor Productivity (TFP) is the portion of output not explained by the amount of inputs (labor, capital, land and livestock) used in production. As such, its level is determined by how efficiently and intensely the inputs are utilized in production. In other word, TFP is known as a "residual share of output growth after accounting for changes in land, labor, and other conventional agricultural inputs." (Diego C, 2006).

other inputs, in first stage it has a positive and significant effect ,however, through time productivity will start to decline., On the other hand, technological driven source of growth becomes more and more sustained and multiplied effect on agricultural productivity when we increase its amount. So that’s why TFP growth is considered as a policy variable for this study.

Ethiopia has gone through three ideologically distinct political regimes: the monarchic regime during 1950-1974, the central planning regime (*Derge* regime) during 1974-1991, and the regime that has been in power since the collapse of *Derge* regime in May 1991, the EPRDF. Each political regime has its Owen impact on agricultural sector directly and indirectly through their economic policies in terms of both access to factors of production and marketing of inputs and outputs. (Shahidur *et al.*, 2007).During monarchic regime the productivity of agricultural sector were poor in performance, to address such problems emperor Haile Selassie passes different national plan conserving on economic growth. The first five year plan (1957-1962) plan were mainly focusing on medium and large industries (that produce consumer goods to satisfy domestic demand) and infrastructural development and also give less attention to agricultural sector productivities. However the plan failed to achieve the expected outcome like most of the agro-industrial projects in the plan failed to provide the expected outcomes and the contribution of manufacturing to GDP remained insignificant within the plan period. In general, imperial Ethiopia's industrial policies failed to have a substantial impact on the economy. After the fall of monarchic regime, *Derge* regime came to power and nationalized rural land, abolished tenancy, ordered all commercial farms to remain under state control, redistributed lands (“*meriet larashu”*). The government then had drawn the Ten Year Perspective Plan with the major objectives of improving the well-being of the people. However, both agriculture and industry grew at negligible rates, due to misallocation of resources to unproductive subsectors (Public enterprises), war, internal conflict and the like. In 1991 the communist military junta seized power and EPRDF took the seat. The EPRDF government mainly focused on private sector development and undertaking a sequence of economic reform program of WB and IMF with three phase:- The first phase reform (1992/93-1994/95) mainly focused on monetary policy and fiscal policy; The second one (1994/95-1996/1997) is based on priority for private sector development by reducing the intervention of government; the third phase (2002/03-2005/06), the government tried to reduce poverty with a stable macroeconomic environment. The EPRDF government also launched the program of ADLI, the objective of ADLI is to enhance sectorial interdependence mainly between agriculture and industry and then secure the overall growth. However, the policy instruments of ADLI are extremely narrow and not adequate enough (Zerayehu .S, 2013).

Agriculture is the mainstay of the Ethiopian economy, which determines not only the growth of all the other sectors by supplying input for their production activities but also the whole national economy. Agriculture has continued to retain its importance in Ethiopia's economic growth contributing about 42% of GDP, with 80% of employment and 70% of export earnings (Coffee continues to be the leading export item accounting for 24% of total export values, oil seeds (14%), Khat (9%), pulses (8%), flower (6%) and live animals (5%) and others (19 %)) and 70% of raw material requirements for large and medium agro-processing industries in 2014 (UNDP, 2014). A large proportion of Ethiopian population (around 85%) lives in rural area on subsistence agricultural activity. According to the results obtained from the 1999/2000 Household Income, Consumption and Expenditure (HICE) and Welfare Monitoring (WM) Survey of the Central Statistical Agency (CSA), about 44 percent of the total population (45% in rural and 37% in urban areas) were found to be below poverty line and 40% of the households are still food deficient using the threshold of 2550 kilocalories per adult equivalent per day. Ethiopia with about 51.5 million hectare of arable land, however, the land tilled by the Ethiopian small-scale farmer accounts for 95% of the total area under agricultural use, Over 50% of farmers operates on at most one hectare and these farmers produce more than 90% of the total agricultural output. Agricultural production in general subsistence and large portion of the country's export is provided by this small agricultural cash crop sector. Small-scale farmers produce 94% of the food crops and the rest 6% of food crop produced by the private and state commercial farms; and 98% of the cash crops like coffee and sesame produced by the small-scale farmers and the remaining 2% produced by the private and state commercial farms (Medic, 2016).

Although agriculture is one of Ethiopia's most promising resource for the economy, the productivity of the sector has been slowed down by a periodic drought (because mostly the agricultural production were rain-fed), poor infrastructure, deforestation, poor farm technology, poor farmer training and extension service, poor health of the farmers, less access to international market of the product of the farmer directly, fragile agricultural research and development. This paper mainly focused on agricultural technological (TFP) improvement on the economy by take into account the other predominant factors that are induced effect on agricultural productivity. In most cases Ethiopian agriculture is characterized by poor technology, the farmer are reluctant to new technology and have no (little) know how of the usage of technological improvement, the land management system is poor, most of agricultural land were owned by small farmer, the share of the private and state commercial farms is too small, therefore these makes it difficult to implement and adopted new agricultural policy and new technology; low resource utilization (e.g. the proportion of cultivated land compared to the total amount of land suitable for agriculture and the amount of water available for irrigation is far below the capacity and thus compels the sector to be rain fed); limited mechanization makes farming labor-intensive and time-consuming; low-tech farming techniques (e.g. wooden plough by oxen and sickles) (Astebeha. G, 2010).

To Meet the current and fast growing future demand of agricultural commodities, improve the welfare of the society especially farmers in Ethiopia will require advanced and mechanized agriculture system. In Ethiopia most of farmers has less than one hectare of land and used the most traditional way of farming (wooden plough by oxen and sickles), and rein-fed farming, these leads to food insecure (subsistence farming), low level of income, unable to keep themselves healthy due to financial constraint, higher suffering from natural disaster like drought. Finally economic growth will be adversely affected by such factors. However this study analysis the economy wide impact of improvement agricultural sector total factor productivity (technology) using DCGE model.

1.2. Statement of the Problem

The agricultural sector is the engine of the economy of Ethiopia, because of its major contribution to the GDP, highly influences directly or indirectly the performances of the other sectors of the economy, the main sources of foreign earnings (70% of export earnings), the main stream of country's capacity to import other materials used in manufacturing and also stresses that macro aggregates (like inflation rate and employment rate) (Haile Kibret 1998). However Ethiopian agriculture has main structural constraints like archaic mode of production and low uptake of technological innovations, which in turn yield low levels of productivity; less effective policies governing such issues as credit systems and land and crop insurance mechanisms, farmer extension and training program, rural infrastructure (education, health, road and electricity), agricultural research and development and low access for farmer of their product directly sold to international market by themselves or without or little intervention by retailer are very limited. These constraints, coupled with the rapid population growth, have significantly contributed to the problem of food insecurity (Yonas Ketsela 2006). In order to alleviate such problem the current government of Ethiopia launched many policy regarding the enhancement of agricultural total factor productivity, the most concerning agricultural policy was ADLI which is hurled around 1993.

The objective of ADLI is to enhance sectorial interdependence mainly between agriculture and industry and then secure the overall growth. However, the policy instruments of ADLI are extremely narrow and not adequate enough. Due to these factors, the ADLI is unable to bring the expected outcome of industrialization and transformation. For instance manufacturing sector accounts for only around 5 percent in GDP and the service sector dominates the structure and the sectorial contribution to GDP growth. ADLI is extremely confined to input supply (like fertilizers and improved seeds) and some credit facilities as most influential policy instruments. Beyond these, there are no other policy initiatives like irrigation, mechanized farming, agricultural research & development and commercial farming during the implementation of ADLI. One of the causative factors, among others, is low and erratic TFP growth in agricultural sector. The factor accumulation, instead of growth rate of TFP, explains the growth trajectory in Ethiopia. The TFP that comprises change in technology, technical efficiency, and allocative efficiency shows a negative growth rate, on average, in the last five decades. It is hard and unthinkable to achieve sustaining economic growth without mainly growth in TFP (Zerayehu .S, 2013).

At the global level although estimates differ somewhat agricultural productivity seems to be growing strongly. Global agricultural TFP growth has accelerated since 1990, averaging 1.7% per annum over the last decade of available data. Global productivity growth is largely due to better performances in emerging economies, economies of the former Soviet Union, and Eastern Europe, however growth is lagging in some Asian and African countries, and has significantly decreased in Sub-Saharan Africa as a whole (OECD, 2001). In 1999 according to Senhadji's estimation the average (mean) agricultural TFP of sub Saharan Africa is 0.43 while that of the world is 0.55. In Ethiopia the growth rate of agricultural TFP most of the time negative based on Sectorial TFP growth using the Regression-based Growth Approach by Zerayehu S. (2013), that was -0.62% (1972-1974),-1.64% (1975-1988), 0.63%(1989-1991), -1.17%(1992-2000). In addition to these the growth rate of agricultural TFP was less than other sector like service and industrial sector TFP, that is, in 1972-1974, 1975-1988 & 1989-1991 the agricultural TFP is lower than the service sector and the industry sector by 4.18% & 3.19%, 3.94% & 3.46% and 4.3% & 5.1% respectively. These lead to a decrease in agricultural output growth rate (7.15%) compared to industry output growth rate (9.66%) and service output growth rate (10.72%). A study by Ferenji and Heidhues (2004) using a cross sectional-time series data from rural farm households for the period 1994 to 2001 also shows a decrease in TFP of Teff production. Finally the effect of negative agricultural TFP and lower growth rate of agricultural output compared to other sectors had adverse effect on the wide economic growth. As mention in the above paragraphs, agriculture in Ethiopia is the backbone of the economy that it is the main source of foreign earning (due to higher share on export items) & household income, almost all cash crop and food crop were produced by these sector, employs large proportion of the population, produce raw materials for other sector, etc, and therefore, any policy shock like TFP (technological) shock of such sector will direct and wide impact on overall economy of Ethiopia. According to world development indicator data the average growth rate of share of agriculture to GDP declined compared to other sector in Ethiopia, however, the service sector took a lion's share of the GDP from 2012-2015. The average growth rate of share of agriculture, service and industry sectors to GDP from 2012-2015 is -6%, 5%, 22.6% respectively, these is due to lower or negative agricultural TFP growth. The decrement of share of agricultural sector to GDP aligned with lower growth rate of agricultural output and TFP may be leads to:-a) restrained amount of agricultural output supply to the market for both consumption and intermediate inputs purpose; these lead to increasing the food price (Inflation) in the economy and impairment the welfare of the societies; b) stress on employment opportunity because is accounts for 70%-80% of employment, therefore, antagonistic this sector enactment have influence on employment opportunity. c) Notwithstanding, agriculture is the main sources of foreign earning and a raw material supplier, mutilation this sector productivity, output growth rate and share to GDP will be a causes of a shortages of foreign currency and depressing the quality & quantity of raw material , these again have adverse effect on other sector especially the industrial and manufacture sector growth. At the end of the amalgamated impact the above issue has adverse impact on the wide economy. Bulk of empirical studies were conducted to try to analysis the economy wide impact of agricultural TFP developing countries including Ethiopia such as; Lulit Metik et al,(2016) ,Fantu Nisrane (2012) , Zerayehu.S (2013) ,Ashenafi. A (2012) and Bonani. N et al (2012) Fantu. N (2012), Senhadji.A (1999), Alemayehu,G ,et al(2002) and Easterly .W(2002). Simeon. E and Christopher. D (2014).

In the above studies most of the papers:-a) give more emphasis on factor accumulation for long run economic growth rather than total factor productivity, b) limited itself on the analysis the impact on technological improvement on agricultural sub-sector like cereal, oilseed, cash crops or single cereal(teff, maize, wheat….), which is unable to analyses the economy wide impact of the change of overall agricultural sector TFP, c) which has used for policy scenarios simulation value of agriculture TFP from some empirical literatures rather than estimated the value of agricultural TFP, this is inconsistent to the case study area, current political and socio-economic situation d) most of their methodology were partial equilibrium analyses, which is weak to address the economy wide impact of the change in agricultural TFP . In this study attempt to address the above gap and analysis the economy wide impact of agricultural TFP through:- a) giving more attention to agricultural TFP rather than factor accumulation for the drive force for long run economic growth, b) make economy wide analysis on the overall agricultural sector TFP shock rather than on a given specific agricultural commodity, c) estimated the value of agricultural TFP using panel data for policy simulation scenarios rather collected from literature, d) using DCGE model to address the economic wide impact and inter-sectorial linkages of the overall economic sectors instead of using partial equilibrium analysis.

1.3. Objective of the Study

The general objective of the study is to analyze the economic wide impact of technological shock on agricultural sector by using a dynamic computable general equilibrium modeling. The specific object of the study are :-

a) Estimate the agricultural sector TFP growth rates and examine their determinants in agriculture sector using panel data analysis.
b) Assess the impact of technological change on agricultural sector on macroeconomic variables (like: - export, import, investment, aggregate consumption, government expenditure etc.).
c) Assess the impact of technological change of agricultural activities on sectorial performance, household income, factor supply, factor income, household consumption expenditure, and household welfare.

1.4. Scope of the Study

The study focuses on analyzing the impact of technological shock on agricultural sector of the Ethiopian economy using the updated EDRI 2009/2010 comprehensive national SAM of Ethiopian economy. In addition attempt will be made to estimate agricultural TFP growth rate and identifying the determinant of agricultural TFP. Finally making simulation for 2017 until 2025, the year in which the country expects to achieve its national plan of middle income country, using Dynamic CGE and analyze the economy wide impacts such as macroeconomic impact, factor income, household income, and household consumption and household welfare analysis of policy shock (TFP shock).

1.5. Limitations of the Study

Thus study focused on the impact of technological shock only on agricultural sector, these will not incorporate all economic sector (service and industry) because of financial and material constraint to run the impact of such policy on all sector of the economy. In addition no more studies were conducted strongly related to the title and the case of the study, which is constraint the availability of literature (reference) to my title and case study.

1.6. Significance of the study

As stated in the above paragraph, agricultural practice in Ethiopia were characterized by traditional way of agricultural practice and farming, these will leads to subsistence way of life of the farmer and most of the rural people were under poverty line compared to the urban dweller. Therefore the government should take action to improve agricultural sector by adopting new technology (fertilizer, herbicide, pesticide, and improved seeds), farmer training and education, mechanized farming, rural infrastructure and the like. This paper discusses the main determinant of agricultural TFP and identifies the most covenant determinants of the variables and make aware the responsible body in order to increase the agricultural productivity without further increase in inputs like land (limited quantity) and labor, because increasing the plot of land or other resource to increase agricultural productivity is difficult. However, increase in TFP is the most vital policy especially in agricultural sector. Additionally, this paper employs general equilibrium analysis in order to incorporate sectorial inter-linkage of the policy shock, unlike partial equilibrium.

1.7. Organization of the Paper

The organization of the paper is as follows: chapter one presents the overall purpose of the study. The second chapter reviews theoretical and empirical literatures on agricultural TFP shock and economic growth. The third chapter introduces the data base (SAM) and specifies the theoretical framework for the Dynamic CGE model used in this study. The fourth chapter discusses the results and findings of the econometrics and the dynamic CGE models. The final chapter, chapter five, concludes and provides implications for policy.

CHAPTER TWO: - LITERATURE REVIEW

2.1) Theoretical Literature Review

2.1.1) Concept and Definitions

The concept of technological progress is closely related to productivity growth. In fact, productivity growth has been shown to be a major source of growth of aggregate output (Solow, 1957) and of agricultural output (Hayami and Ruttan, 1985). Hayami and Ruttan (1985) have shown that agricultural output can grow in two main ways: an increase in use of resources of land, labor, capital and intermediate inputs or through advances in techniques of production through which greater output is achieved through a constant or declining resource base. TFP captures the effects of changes in technology, institutions, and other productivity shocks, but it gives little insights as to what takes place inside the black box of technology. TFP is often referred to as technology, but it is technology in the widest possible sense. It is not just new ways of constructing buildings, new machines, or new sources of power, but changes in work organization, efficiency of government regulations, degree of monopoly, literacy and skills of the workforce, and many other factors. In essence therefore TFP measures productivity growth, capturing technological change in the production process. It is often measured by the Solow residual in a neoclassical production function. (US President's Council of Economic Advisers, 2001).

Productivity is defined as the efficiency of a production system between the quantity of output and the quantity of input used to generate a given output. It is also defined as the production value (or quantity) divided by the amount of factors consumed in the production process. Generally, It is a ratio of output to input (Productivity = Output/Input). The higher productivity arise from higher performances improvement (production increases) and higher profits (minimal factors costs, better selling prices, marketing capacities, etc.).The two most commonly used measures of productivity are single (partial) factor productivity (PFP) and total (multifactor) factor productivity (TFP), Partial factor productivity (PFP) refers to the measure of produced output per unit of each input used.

In addition according to Darku et.al, (2013) the most common partial productivity measures for the agriculture sector are crop yield and labor productivity, which refer to the amount of output per unit of a particular input. Specifically, crop yield is a measure of output per unit of land, and normally is used to access the success of new production practices or technology. Similarly, labor productivity measures the output per economically active person (EAP). The partial productivity measures could be misleading because they reflect the joint effect of a host of factors and might not give any clear indication of why they change over time. For example, land and labor productivities may rise due to increased use of other inputs such as tractors or fertilizers, or to a move to high value crops. Therefore the interest shifts to the total factor productivity. Any growth in output that is not explained by some index of input growth is attributed to changes in technology or more broadly TFP. TFP measures the net growth of output per unit of total inputs. As such, its level is determined by how efficiently and intensely the inputs are utilized in production. Thus, TFP growth is a catch–all measure that captures changes in efficiency in addition to pure technical change in the sense of shifts in the production function. TFP is regarded as the more accurate productivity measure than the partial productivity measure. Total factor productivity (TFP) can be defined as a ratio of aggregate output produced relative to aggregate input used (Frija *et.al*, 2015).

Total factor productivity (TFP) measures the increase in total output which is not accounted for by increases in total inputs. The level of TFP can be measured by dividing total output by total inputs. The TFP index is computed as the ratio of an index of aggregate output to an index of aggregate inputs. Growth in TFP is therefore the growth rate in total output less the growth rate in total inputs (Kathurial *et.al*, 2011).

2.1.2) An Overview of Total Factor Productivity (Technology) Progress

It is important to be able capture the effects of methods of production change over time on output. Capturing such effects can ideally be done within the production function framework. Starting with a simple production relationship in which output depends on capital input K, and labor L, the production function can be expressed as:

$$Q = f(K, L) \qquad \text{(I)}$$

Where Q (the output) depends on how much of K and L is used. If the levels of K and L are increased/reduced, then it is expected that Q will also correspondingly increase/decrease. However, Q can also increase by using the same level of K & L. This is possible if a superior technology is used in the production process. However, output growth can also be attributed to other factors other than growth in the conventionally defined inputs. When this is the case, then technical progress has taken place. In terms of the production relations, such change represents a shift in the production frontier and can be defined as:

$$Q = A(t) f(K, L) \tag{II}$$

Where $A(t)$ represents all the influences that go into determining Q besides K and L. $A(t)$ Changes overtime represent technical progress or TFP. It is important to note that technical change may influence output in two distinct ways. First, technical change may influence output by affecting not a single input but all the inputs. This would be a case of neutral technical progress or disembodied technical progress. Equation (I) above is a case of neutral technical progress. The second case is where technical change affects output by augmenting either capital (capital augmenting technical progress) or labor (labor-augmenting technical progress). These two cases are commonly referred to as disembodied technical progress and can be represented as:

$$Q = f(A(t)K, L) \tag{III}$$

and

$$Q = f(K, A(t)L) \tag{IV}$$

Equation (3) represents the capital-augmenting technical progress while equation (4) is a case of labor-augmenting technical progress (Odhiambo et.al, 2003).

A) Embodied technological changes: -

Embodiment simply means that because of technological advance, the new inputs are more efficient than the old inputs or improved technology which allows increase in the output produced from given inputs with investing in new equipment. New technological changes made are embodied in the equipment's. Example, the idea that most technological progress is embodied in new capital equipment, and that the benefit of new technology is not realized without introducing new capital equipment. More recently, as information technology (IT) capital has drawn increasing attention, this idea has often been revisited. This is partly because the majority of benefits arising from IT are realized only by employing the latest machinery. Taking personal computers (PCs) as an example, while new PCs produced in 2007 certainly perform much better than those produced in 2000, regardless of the type of PC, there is no way of enjoying the technological benefits they bring without buying and using a new one.

B) Disembodied technological changes:

This means improved technology which allows increase in the output produced from given inputs without investing in new equipment. Example the above two factor augmented (labor and capital augmented) and neutral technical progress.

C) Factor accumulation

This refers to an increase in the quantity of factors of production (labor, land, capital, investment, saving, natural endowment etc) in the production process. The more factors injected into the economy, the more goods and services the economy produces. However, such accumulation of factors does not have unlimited contribution to economic growth. Rather it is subject to a diminishing return to scale and scarcity of factors. This means that the economy wide growth rate in this framework is likely constrained by factor scarcity, factor depleting, and diminishing factors of production. However, others indicate that factor accumulation of saving and investment should be considered as a necessary but not sufficient condition for sustaining economic growth and transformation (Todaro and Smith, 2011). The decreasing return to scale in factor accumulation raises the need for an alternative framework of factor productivity to complement, not to replace. This leads to the analysis of factor productivity framework (Zerayehu, 2013).

D) Factor Productivity

In addition to decreasing return to scale after a certain level of factor accumulation, and the scarcity of factors of production, many studies show that factor accumulation does not explain catching up growth rate. This means that factor accumulation produces only a transitional effect on growth, not a permanent effect. The other typical nature is the fact that factor accumulation is persistent while growth is not persistent, but erratic. So this allows looking for something else that principally drives the long run economic growth. It is increasing the TFP that complements the contribution of factor accumulation and enables the country to achieve a permanent long run economic growth (Zerayehu, 2013). The change in TFP growth refers not merely to technological change. Rather, it embraces all changes in technology, technical efficiency, allocative efficiency, economies of scale effects, and the like. It also considers that increase the productivity of all factors of production like technical change, human capital via education and health, development expenditures etc. (Hafiz *et al*., 2010). It was Solow (1956) who first questioned the accumulations view and then kicked off the debate that growth involves technical change. He found that seven-eighth of output growth attributed to TFP growth in his study. In general, the recent theories suggest that TFP in the sense of change in technology, knowledge, human capital and spillover effect drives the long-run growth while accumulation of factors does not explain long run growth. This does not mean that factor accumulation is irrelevant for long-run growth and structural change process. Without adequate factor accumulation, increasing TFP can be limited to some extent. In general, many studies indicate different source of growth. This study believed that technology-led productivity growth is the source of sustaining growth.

2.1.2.1) Basic Economic Growth Model about Technological Changes

Primary factors of production under a basic model are capital stock (roads, bridges, factories, land, etc.) and labor (economically active population). Output is a function of capital and labor. At a national level, an aggregate production function can be represented by the formula $Y = F(K, L)$ where Y stands for output, K represent capital and L symbol for labor. Increased output (Y) depends on increases in the capital stock (K) through investment and depreciation, and increases in labor supply (L) through population growth. The amount of investment in capital stock depends on savings and is calculated by multiplying the average savings rate in a country by national output. Labor supply is based on demographics. As capital and labor increase, economic output grows.

A) Solow (Neoclassical) Growth Model

The neoclassical model states that in the long term, the growth rate of output per worker is dependent on the rate of labor-augmenting improvement in technology, which is determined by factor(s) not contained in the model (also known as exogenous factors). The model implies that all economies that use similar technology, which could improve over time, should have converging productivity growth rates (Solow 1991:398). Permanent differences in productivity levels are caused by faster/slower population growth or higher/lower savings rate. Lower productivity could be due to climate deficiencies or other factors not accounted for in the model (Solow 1991:398).In the 1950s, MIT economist Robert Solow presented a new model of economic growth that addressed limitations in the Harrod-Domar model[2]. He replaced the fixed-coefficients production function with a neoclassical production function. This model allowed for substitution between the factors of production so that the relative endowments of capital and labor could be reflected (rather than the fixed ratios required by the Harrod-Domar model). The neoclassical production function has curved, rather than *L* shaped, isoquants allowing flexibility in using different combinations of capital and labor. Output can be expanded in one of three ways: (1) increases through fixed and equal portions of labor and capital, (2) increases in capital, or (3) increases in labor. The Solow Growth Model assumes a production function with the property of diminishing returns where each additional increment in capital per worker results in less output. (4) However, technological change is seen as increasing productivity. The neoclassical production function showed increasing technology or knowledge as labor augmenting and increasing output. Solow assumes technology increases independent (exogenous) of the model in two forms: mechanical (improved machinery, computers, etc.) and human capital (improved education, health, worker skills, etc.). Key determinants of growth are population growth and technical change and over time poor and rich countries incomes should converge[3]. Robert Solow also developed a procedure, ―growth accounting‖ or ―sources of growth analysis‖, to focus directly on the contribution of each term in the production function. The objective was to determine what proportions of recorded economic growth could be attributed to growth in capital stock, growth in the labor force, and changes in overall efficiency. Using the formula $Y = F(K, L, A)$ where Y is output, K is capital, L is labor, and A is a parameter meet to capture the effects of things other than capital stock and labor supply which might influence growth (increasing technology, worker skill levels, education, health, institutions, etc.). A is generally referred to total factor productivity (TFP). Since A captures not only efficiency gains but also the net effect of errors and omissions from economic data, the residual A is sometimes referred to as a measure of our ignorance about the growth process. When Solow modeled data for US GNP from 1909 to 1949 of increased output less than one half of the gain could be explained by increased inputs in labor and capital. With more than fifty percent of

[2]Economic growth model based on a fixed-coefficient, constant returns to scale function (this function assumes that capital and labor are used in a constant ratio to each other to determine total output and fails to account for technological change and productivity gains considered essential for long-term growth and development.

[3]The surprising implication of the Solow model was that the savings rate didn't really matter for the growth rate. The Harrod-Domar model suggested that all poor countries had to do was to double savings to increase growth but the Solow model suggested that the effect of such capital deepening would be transitory as sooner or later the nation ran into diminishing returns. Only population growth and technological change could promote long term economic growth.

growth attributable to the residual, logic would dictate that there must be a significant gain in productivity coming from one or more efficiency enhancing factor(s) (technical change, increased knowledge, innovation, entrepreneurship, etc.) but the problem lies in actually identifying the factors affecting increased productivity. Solow-Swan and the Cass-Koopmans- Ramsey models that technology and innovation play a fundamental role to avoid zero growth in the steady state and allow for growth in capital and output in the long-run. However, they have been introduced in the previous models only exogenously, by a productivity parameter growing at a rate taken as given. However, it has always been believed by the most theorists that technology improvements depend on decisions of economic agents as much as capital accumulation. In order to fix the shortcoming of the previous exogenous models in explaining what the forces that draw technological change are, there have been many attempts to endogenize technology.

To be fair to the Solow-Swan model, however, we would not expect convergence for economies with different exogenous parameters (population growth and technology). For example, we know that a higher rate of technical change (higher-level for the parameter g in our model) is the primary factor associate with a higher rate of per person output growth. We would not expect two economies to converge if one has a higher rate of technical change. If one of the other parameters of the model differs, but the rate of technical change is the same, we would expect per person output growth rates to converge, but the per-person levels may vary. From the Solow-Swan model, we get the important conclusion that changes in either the saving rate or population growth rate cannot explain persistent growth. If technology is not improving, per person output will increase when either the savings rate increases or the rate of population growth decreases. However, this increase in per person output is a onetime increase. The Solow-Swan model tells us that only a steady improvement in technology can explain the persistent growth in per person output that we observe in many western economies.

Basic building blocks of the Solow model

- A production function

$$\boldsymbol{Y_t = F(K_t, L_t, A_t)}$$

  - This is a hugely important concept.

- Once we assume this, then we are saying that any growth has to be the result of more capital, more people or better technology!

- Exogenous population growth

$$L_t = (1 + n)L_{t-1}$$

This is actually a really important assumption

- A constant rate of capital depreciation: δ
- An exogenous savings rate

$$S_t = sY_t$$

- A closed economy, so savings equals investment

$$I_t = S_t$$

- Exogenous technological progress

$$A_t = (1 + g)A_{t-1}$$

B) Paul Romer (New) Growth Model

In his model Romer (1990b) claims that growth depends on technological development, which in turn comes from the decisions of individuals whose goal is to maximize their profits or utility. The peculiar feature of this model is that technology is neither a private nor a public good; instead, it is a non-rival, only partially excludable good. In this manner the equilibrium cannot be with perfect competition, but only monopolistic competition can be supported. Paul Romer believes that if technology is endogenous, explained within the model, economists can elucidate growth where the neoclassical model fails. When the level of technology is allowed to vary, you can explain more of growth, as DCs have higher level than LDCs. Variable technology means that the speed of convergence between DCs and LDCs is determined primarily by the rate of diffusion of knowledge.

Specifically, we have said that the long run properties of growth models are determined by whether there are decreasing, constant, or increasing returns to scale *in the produced inputs*. Because this issue has had a profound impact on modern growth theory, it is worth digressing to consider it in more detail. First of all, we need to be clear about what we mean by a "produced input" or "produced factor." A better term might be "endogenous input" because we consider an input to be produced if it is created endogenously within the model through the use of other factors of production. Since pure labor is exogenous in all of the growth models we have studied, it is not considered produced factor. For new growth theorists like Romer, innovation or technical change, the embodiment in production of some new idea or invention that enhances capital and labor productivity, is the engine of growth. The endogenous theorist, whose message is continuous technological innovation, is the strongest antidote to the limits-to-growth literature.

Neoclassical theorists assume that technological discoveries are global public goods, so that all people can use new technology at the same time. Indeed, it is technologically possible (but not historically accurate) for every person and firm to use the internal-combustion engine, the transistor, the microcomputer, and other innovations. For new growth economists, however, technological discovery results from an LDC's government policies (the neoclassical growth theorists have no role for the state) and industrial research. Neoclassical economists assume that the innovator receives no monopoly profits from their discoveries. However, because individuals and firms control information flows, petition for patents to restrict use by rivals, and charge prices for others to use the technology, new growth economists assume a temporary monopoly associated with innovation.

According to Romer (1999:13), technological advances occur as a result of "things that people do". Even if discoveries are made only by chance, more discoveries will be made if more researchers work to produce them. A factor that induces research in the private sector is the fact that discoveries are partially excludible and as such do not meet one of the criteria needed to be classified as a public good. Individuals or firms have some control over the information produced by most discoveries. This mere fact enables the individual or firm that makes a discovery to charge a price that is higher than zero and so earn monopoly profits because information has no opportunity cost. Technological change not taken as given, but generated by maximizing individuals responding to market incentives is to introduce market power in the intermediate goods sector, While the traditional growth theory considered only two factors of production, namely capital and labor, this new growth theory adds a third, technology. These types of models are sometimes called Schumpeterian models because Schumpeter emphasized the importance of temporary monopolistic power over discoveries, as a motivating force for continued innovative processes. Large research and development and technology-intensive companies such as Microsoft and IBM, expressed interest in the new growth theory because of its view of monopolistic power and changes in institutional arrangements suggested by the theory. IBM (1999:3) highlights the importance of having some monopolistic power (as proposed by the new theory) by pointing out that no one would "spend their own resources to produce a new idea if they didn't have any monopoly power over it. Allowing companies' monopoly power over their new ideas, through patents, creates incentives for other firms to go out and make discoveries of their own". Financial analysts have also taken note of this "ideas versus objects" point and are following through on it in their valuations of the companies listed on stock markets.

Romer's analysis resembles the work of Arrow on learning-by-doing. However, Romer enhances the concept of physical capital by adding investment in knowledge. Knowledge cannot be patented perfectly to obscure it from rivals in the industry or the economy. Investment in knowledge by one business would therefore spill over to its rivals and enhance their production possibilities. In the simple Solow model, advances in technology come from outside, there is no way to reallocate resources to get faster technological change, so the *A* term is not a produced input. However, in the R&D model, *A* is produced directly by labor and capital (and *A* itself). Adding more resources to the R&D production function leads to more rapid accumulation of knowledge capital *A*. Thus, the evolution of *A* is endogenous and it is a produced input in this model.

Firm's production function

$$\boldsymbol{Y(t) = AK(t)^{\alpha}L(t)^{1-\alpha}}$$

Where A is the Total Factor Productivity (TFP).

Technology A depends on Capital Stock. The higher the capital stock the more the economy is able to use new technologies

$$\boldsymbol{A = BK^{1-\alpha}}$$

Where K is the aggregate level of capital stock and B is the learning factor (positive externality). Imposing symmetry across firms and substituting in the production function, we get the aggregate production function.

$$Y = BKL^{1-\alpha}$$

Assuming that population L is constant and equal to 1. Then, the aggregate production function becomes,

$$Y = BK$$

This production function is characterized by constant return to scale.

The low of motion of capital is

$$\dot{K} = sY - dK$$

Hence the growth rate of capital is

$$\frac{\dot{K}}{K} = s\frac{Y}{K} - d = sB - d$$

Given that$\frac{Y}{K} = B =$ constant, $\cdot\frac{\dot{K}}{K} > \frac{Y}{K}$. If sB > d ⇒ the growth rates are positive.

The rate of growth of A is

$$\frac{\dot{A}}{A} = (1-\alpha)\frac{\dot{K}}{K} = (1-\alpha)(sB-d)$$

Contrary to the Solow model, the rate of growth of technology depends on the rate of growth of capital. At the same time technology affect capital. Growth is an endogenous process. An increase in savings means that the growth rate increases permanently.

2.1.2.2) Major Determinants of Agricultural TFP Growth

TFP is the driving force of long run growth and has a permanent effect on structural change. It also generates an increasing return to scale and sources of efficiency. It comprises change in technology; allocative efficiency, technical efficiency, economies of scale and the like. Technical efficiency in this regard means producing maximum output from the minimum quantity of factors of production. Allocative efficiency; on the other hand, refers to the production level where marginal utility of the good equals to its marginal cost. This indicates that allocative efficiency accounts for optimal distribution of goods and preferences of consumers.

In general, it is the growth of TFP that creates synergy and speeds up the process of economic transformation and perpetual economic growth as well as enhances the welfare of the society (zerayehu, 2013). Therefore, what are the chief determinants and sources of change in TFP in order to articulate a sound economic policy?

A) Fertilizer

Refers to anything added to the soil intended to increase the amount of plant nutrients available for crop growth. Usually fertilizers are divided into two parts, Natural and chemical. Examples of natural fertilizers are farmyard manure and wood ashes while chemical fertilizers are DAP (Di-Ammonium phosphate) and UREA (Ammonium Nitrate). Fertilizer significantly enhances natural soil nutrients and as a result per acre production is increased. However, the impact of fertilizer on agricultural TFP is non-linear. There would be an optimal use of fertilizer per acre. Excessive application of fertilizer may result in reduced production due to harm caused to plants. Use of fertilizer must not exceed the optimal amount. Proper use of fertilizer leads to highest output per acre. Sabir and Ahmed (2003) found use of fertilizer has been a significant determinant of agriculture TFP in Pakistan. The expected sign of the coefficient on fertilizer is positive.

B) Pesticides:

Pesticides are chemicals and vaccination useful for the mitigation, control or elimination of pests, insect and disease which are troublesome or harmful to crop and livestock. Insecticides, vaccination, herbicides and fungicides are all considered as pesticides. Since, the impact of Pesticides on agricultural TFP is based on the requirement level, which means that the farmer must have a knowledge about how much the maximum amount of Insecticides, herbicides and fungicides, on what types of crop make treatment, what are the contingency mechanism from contamination to the human being and animal. However the treatment beyond the requirement level will harm the crop or livestock. Ashenafi (2012) found that Pesticides has significant effect on agricultural total factor productivity.

C) Training & Extension

A population that is well educated and well trained helps a society to increase its ability to acquire as well as use relevant knowledge. Human capital, for example, in the form of level of education, has an important effect on TFP because of its role as a determinant of an economy’s capacity to carry out technological innovation and, for developing countries in particular, to adopt (and adapt and implement) foreign technology. Extension & Education involves a dissemination of research results to farmers through information distribution, training and demonstration. It may also indirectly influence the agricultural research process by conveying feedback from farmers to researchers that may improve future research. Effective agricultural extension should improve productivity. Agricultural research expenditures affect productivity after a time lag. First, a particular research project may take several years to complete. Second, it takes time for farmers to learn and adopt the innovation. The sooner the benefits from research are received by farmers and consumers, the higher will be the rate of return to that research expenditure. Agricultural extension system aims to reduce the time lag between development of new technologies and their adoption. Extension agents disseminate information on crops, livestock, and management practices to farmers and demonstrate new techniques. They also directly consult with farmers on specific production and management problems. Unlike research, it is reasonable to assume that extension has an immediate effect on productivity.

D) Infrastructure

It also enhances agricultural productivity through expanding like road, which has significance to the farmers' easy transport of its produce to the market where they fetch a relativity higher price, health service (hospital, clinic) which improve the rural society health and equip them with higher productivity. The amalgamation of this factor and the other factors infrastructure enhance agricultural total factor productive. Infrastructures considered a fixed factor that contributes positively to agricultural growth and productivity Investment in public capital, in particular, physical infrastructure, accounts for the largest share of budgets in many countries. The role of infrastructure is to expand the productive capacity by increasing resources and enhancing the productivity of private invested capital. A few studies have found a significant positive relationship between infrastructure and agricultural productivity (Yee *et al.,* 2000). The most obvious example of how public investment in infrastructure might affect agricultural productivity is through investment in public transportation and in irrigation infrastructure. As an example, an improved highway system can allow for better market integration of farmers and can reduce costs of acquiring production inputs and of transporting outputs to market.

E) **Research and Development (R&D)**:-

Agricultural research and development (R&D), in general, contributes to agricultural growth and total factor productivity (TFP) by increasing crop and livestock yields through development of new technologies (that is, new varieties and techniques) and increased technological diffusion and adoption. Successful R&D activities in introducing and disseminating new technology to increase agricultural productivity require strong support and commitment from extension agents. Positive and significant impact of public research on TFP is actually consistent with other theoretical and empirical findings from literature (Thirtle et.al, 2003).The results of agricultural research include higher yielding crop varieties, better livestock breeding practices, and better farm management practices. Agricultural research is required not only to increase agricultural productivity, but to keep productivity from falling. For example, yield gains for a particular plant variety tend to be lost over time because pests and diseases evolve that make the variety susceptible to attack. Thus, a large share of agricultural research expenditures is devoted to maintenance research.

Farmers benefit from agricultural research in the short run because of lower costs and higher profits. However, the long run beneficiaries of agricultural research are consumers who pay lower food prices. Agricultural research also helps maintaining competitiveness of a given country in world markets. Agricultural research can also reduce inequality in incomes and living standards because lower food prices benefit low-income people more than high-income people (Low-income people spend a larger share of their income on food than do high-income people.) Moreover, the major portion of public agricultural research is paid for by taxes from middle-income and high-income people.

Private agricultural research is mainly performed by manufacturers of farm machinery and agrochemicals, and by food processors. Public agricultural research is performed in national agricultural experiment stations and other universities. Both public and private research has positive effects on agricultural productivity (Frija et.al, 2015).

F) **Openness to international trade (TO)**.

Trade openness (Trade liberalization) enhances competition and efficiency in production, allows for technology & human capital transfer, expected to boost international trade, influencing trade patterns, increasing domestic output, thus improving productivity. Due to these and other factors trade openness has powerful forces for increased TFP. Trade theory also hypothesizes that trade expansion would lead to improved (labor productivity as well as total factor productivity (TFP)) due to gains stemming from economies of scale. Openness to trade is proxied by the ratio of total exports plus imports to GDP. The expected sign of the coefficient on Trade openness is positive. Frankel and Romer (1999) estimate that raising the ratio of trade to GDP by 1 percentage point would increase income per capita by 2.0 percent.

G) Irrigation

The intensity of irrigation expresses man's dynamic attempts to overcome the environmental limitations in the transformation of many of the barren areas into the agriculture areas. It is an important indicator to determine the cropping pattern and agricultural productivity. The intensity of irrigation controlled by various factors such as source of irrigation, quantity and quality of water supply, intensity of network of water channels etc.

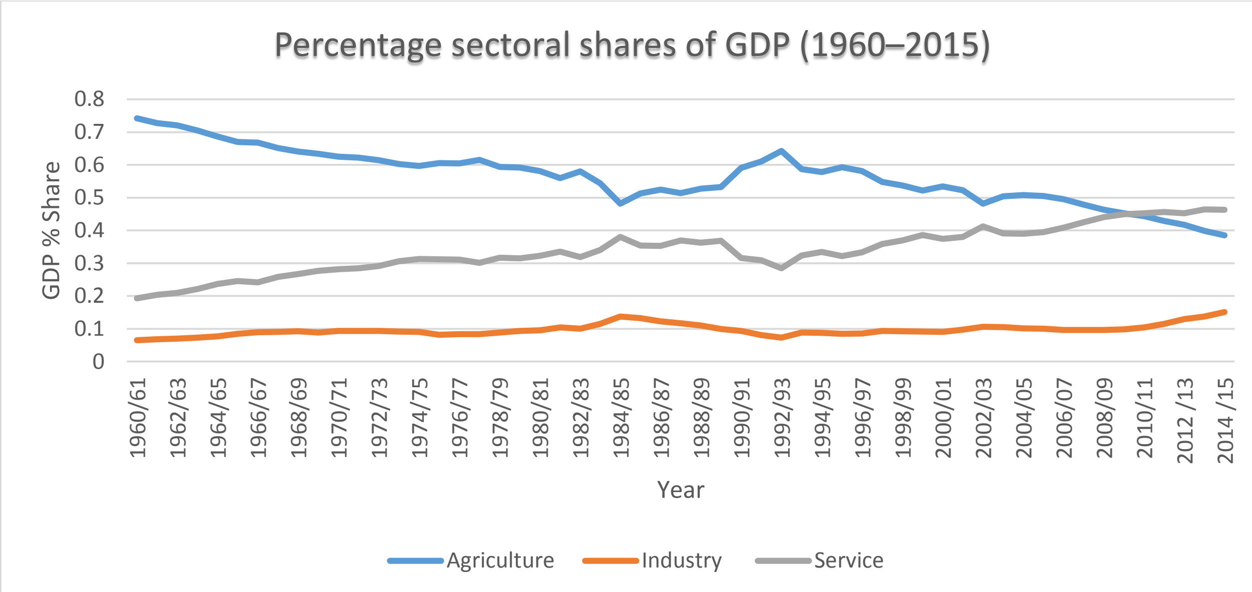
2.1.3) Agricultural Technological Change and Economic Growth

2.1.3.1) Over View of Ethiopian Economy and the Agricultural Sector

Ethiopia has experienced rapid economic growth since 2005, with gross domestic product (GDP) growing at an average rate of 10.5 per cent per annum in real terms for the period between 2004–05 and 2012–13 (MoFED ,2013). This makes Ethiopia one of the fastest growing countries in the world. The rapid economic growth has a multifaceted effect on a number of social, economic, and political domains. Considering 2015, the year the first Growth and Transformation Plan (GTP) the country's comprehensive five-year development plan with targets aligned to the aim of achieving middle-income status by the mid-2020s—ends, it is a good time to explore the pattern of economic growth in Ethiopia and the relevant growth opportunities and challenges.

Available evidence suggests that economic growth in Ethiopia has been accompanied by signs of a structural shift away from traditional and primary sectors and towards secondary and tertiary ones. For instance, the pace of output growth has been decreasing in agriculture whereas growth rates of industrial and service sectors have been increasing. As a result, the share of agriculture in GDP is now comparable to that of the service sector—a significant change from a couple of decades ago.

Figure 2. 1 Percentage sectorial shares of GDP (1960–2015)



Source: Own calculations using data from the EEA database 2015.

The Ethiopian economy has grown at an average rate of 11 per cent over the period 2005/14. Nevertheless, there are challenges to be tackled to ensure that such changes are accompanied by shifts in sectorial proportions in terms of factor use and contribution to GDP. The share of agricultural value added in GDP has declined by about 35 percentage points between 1960 and 2015 (from 74 to 39 percent; see above Figure). Moreover, measures of sectorial contributions to GDP growth reveal that the role of agriculture, which jointly led the growth momentum with the service sector during the period of PASDEP, has declined during the first phase of the GTP. The industrial sector, which had a declining contribution to growth during PASDEP, has reversed its momentum and doubled its contribution to growth during the first phase of the GTP. The changes in the growth contributions of sub-sectors also corroborate the fact that changes in the structure of the economy are occurring across sectors, from agriculture to service and construction. Crop production, traditionally a dominant contributor, has been overtaken by construction and wholesale and retail trade sub-sectors. The increase in the industrial sector's contribution to growth has largely originated in the construction sub-sector. If the process of structural transformation in the Ethiopian economy has to be judged by the historical patterns of industrialization, there is still a lot to be done. About 70 per cent of the decline in GDP share of agriculture was accounted for by the service sector with the remaining 30 per cent going to the construction sector. In contrast, the share of the manufacturing sector in GDP hovered around 4.4 per cent in 2013/14, which was only 0.2 percentage points higher than its share in 2005 (MoFED, 2013). Studies (Bigsten and

Gebreyesus 2007, Söderbom et al. 2006) identify, among others, limited access to credit, declining returns to capital, and limited backward and forward linkages as important constraints faced by the manufacturing sector in Ethiopia. Finally the decrement in share of agriculture to GDP may has been a lot of challenges like higher unemployment (it account for 70-80% to employment opportunity), foreign exchange constraint (it account for 70% of export earning), increasing in food price (inflation), higher rural to urban migration, lack of raw material for other sector (it account for 70% of raw material requirements for large and medium industries that are agro-processing) and etc. Therefore the government should transform the structure of the economy by taking into account the important role of agricultural sector to the overall economy and make more intention to agricultural sector.

Sources of growth

This section explores the sources of aggregate and sectorial growth using Solow decomposition analysis. Table below reports half-decade averages for GDP growth and the part of that growth which originated in increased use of labor and capital as well as changes in total factor productivity (TFP). Perhaps not surprisingly, the contribution of all factors can be noted to increase in later years. Labor (employment expansion) continues to be an important source of growth. Interestingly, the role of labor quality improvements (changes in labor composition) has edged upwards again, although from a very low base and it is still small. This is most likely linked to the expansion in education and elements of structural change outlined later. There is also some micro evidence suggesting capital intensity is rising and, more specifically, generating discernible productivity differentials in industry. Finally, consistent with Ethiopia's significant exposure to shocks in the past, changes in TFP were negative or low as a source of growth up to 2004. In contrast, they have been the largest contributor during the decade up to 2014. Nevertheless, TFP growth and its share in GDP growth appear to diminish slightly in the last half-decade (2010–14), perhaps indicative of things to come (Alemayehu et.al, 2015).

Table 2. 1 Aggregate growth accounting

Period	GDP growth (%)	Contribution of employment growth in GDP growth (%)	Contribution of labor composition growth in GDP growth (%)	Contribution of non ICT capital service growth in GDP growth (%)	Total factor productivity growth (TFP) (%)
1990-94	-1.23	0.96	0.03	1.01	-3.23
1995-99	4.37	1.49	0.02	2.42	0.43
2000-04	4.00	1.39	0.01	1.88	0.72
2005-09	9.80	2.01	0.00	3.10	4.69
2010-14	9.51	2.07	0.06	3.42	3.96

Source: Alemayehu et.al, 2015 Sectorial TFP growths and Sources of Growth

The Ethiopian economy in this regard manifests a multifaceted performance depending on the political economic policy regimes such as the feudal-capitalism (up to 1974), socialism (1975-1988), mixed economy (1989-1991), more of liberalization (1992-2000) and the pro-poor growth regime (2000 to date). The sectorial growth accounting approach decomposes the source of growth into labor, capital and TFP as presented in table 2.3. The empirical results by Zerayehu, 2013 indicate that the accumulation of labor factor is the dominant source of growth in the agriculture sector over the period 1972-2010. Both capital and land positively contribute to the average growth rate of agriculture while the agricultural TFP growth rate is negative on average in 1972-2010. Following the pro-poor economic policy shift, the agricultural TFP growth takes the lead in influencing the agricultural growth during 2001-2011. This might be because of the pro-poor growth strategy that addresses the rural-poor that are heavily engaged in agriculture.

In the table below agricultural growth dominates by accumulation of labor growth rate in the almost all period, followed by capital contribution. The TFP growth still remains negative in the agriculture sector in 1972-2010. Regarding industrial TFP growth, accumulation of capital dominates the growth rate of the industry value-added in the same reference period, followed by labor contribution. The TFP growth still remains negative as manifested in the agriculture sector in 1972-2010. During the period 1992-2000, the industrial TFP growth positively contributes and takes the lead in the contribution to growth rate of the industry value-added. This is mainly due to the fact that many industrial firms are encouraged and participated as the economy was free from the bondage of socialism in 1991. In the service sector, the contribution of capital to the service value-added is dominant during the socialist and liberalization regimes while the TFP growth dominantly influenced the service value-added during 1972-1974 and 1989-1991. In short, sources of growth vary with the types of economic sectors and policy regimes. In a nutshell, labor is the dominant source of the agricultural growth while capital deepening is the big source of growth in industry and services in 1972-2011, regardless of the various political economy regimes. However, the sectorial TFP growths negatively affect the growth rate of each sector in 1972-2010. This negative growth rate possibly reflects the lack of efficiency and the shortage of technological change in the economy. This leads to deterioration of productive efficiency and erratic economic growth. In addition to this negative performance, the sectorial TFP growth rates are highly fluctuating overtime and across sectors in the entire period. Therefore, such TFP growth is the bottleneck to the long run growth and structural change, creating severe economic debacles and a deadlock situation (Zerayehu, 2013).

Table 2. 2 Sectorial TFP growth using Growth Accounting Approach (%)

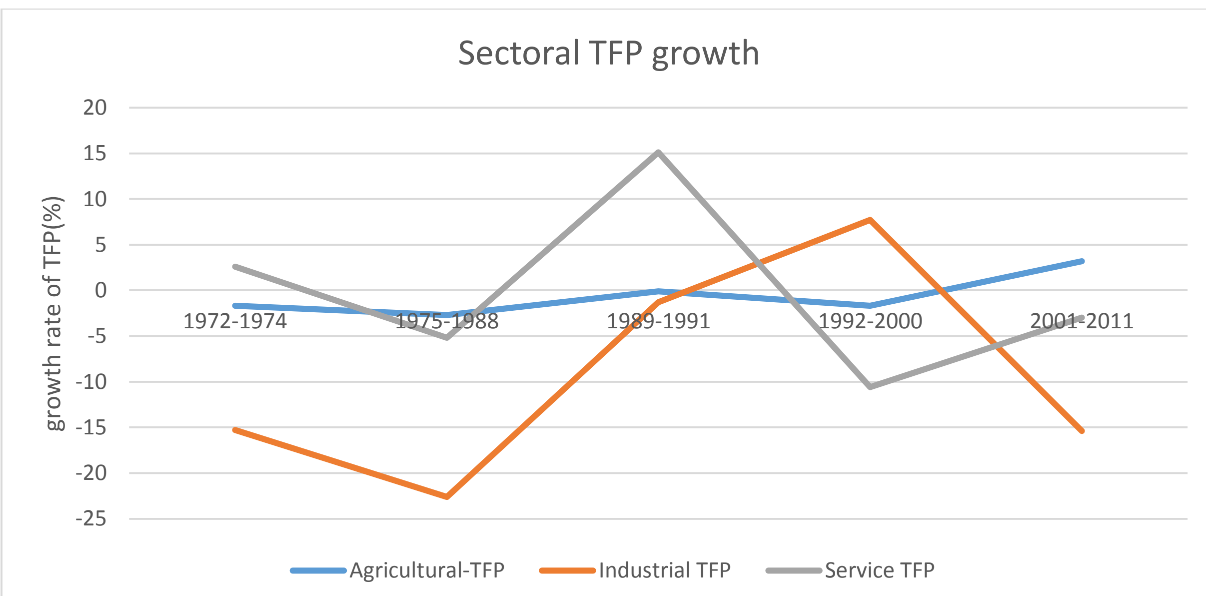
Sectorial decomposition of GDP growth rate	Political economy regimes					Average for 1972-2011
	1972-1974	1975-1988	1989-1991	1992-2000	2001-2011	
Agricultural GDP growth rate	1.5	1.0	3.4	1.6	7.1	3.1
Contribution of labor	1.4	2.3	2.7	2.1	2.1	2.2
Contribution of land	0.1	-0.1	-0.1	1.0	0.5	0.3
Contribution of capital	1.7	1.6	0.9	0.3	1.4	1.2
TFPG- agriculture	-1.7	-2.7	-0.1	-1.7	3.2	-0.6
Industry GDP growth rate	5.2	4.1	-6.3	4.1	9.7	4.9
Contribution of labor	1.2	0.8	1.0	0.3	2.2	1.1
Contribution of capital	19.2	25.9	-6.1	-3.8	22.9	15.5
TFPG- Industry	-15.3	-22.6	-1.3	7.7	-15.4	-11.7
Service GDP growth rate	5.5	3.9	2.7	4.2	10.7	5.9
Contribution of labor	0.8	0.5	0.7	0.2	1.5	0.8
Contribution of capital	2.1	8.6	-13.1	14.6	12.3	8.8

TFPG- Service	2.6	-5.2	15.1	-10.6	-3.0	-3.7

Source: Zerayehu, 2013

Figure below shows that the growth rate of TFP in the agriculture, industry and service moves stochastically around zero overtime. However, the fluctuation varies across sectors. In the case of agriculture, the dynamics of TFP growth rate seems less swinging as compared to the other two sectors because most of agricultural TFP (technology) shock was a limited extent compare to other sector. The growth path of the industrial TFP highly fluctuates across time with some outliers due to most advanced technology shock the sector occasionally faced relative to other sectors. Such variations indicate that factors that are heavily responsible for variations in the sectorial TFP growth rate are likely to be different per each sector. Lastly service sector TFP also oscillate higher than agricultural TFP and less than industry TFP, but it is increasing from 1993 to 2011, because of human capital development.

Figure 2. 2 The Trend of Sectorial TFP growth



Source: Zerayehu, 2013

2.1.3.2) The Green Revolution

Green Revolution refers to a series of research, development, and technology transfer initiatives, occurring between1943 and the late 1970s that increased industrialized agriculture production in India; however, the yield increase has also occurred worldwide. The initiatives involved the development of high-yielding varieties of cereal grains, expansion of irrigation infrastructure, and distribution of hybridized seeds, synthetic fertilizers, and pesticides to farmers. The term "Green Revolution" was first used in 1968 by former USAID director William Gaud, who noted the spread of the new technologies and said the Green Revolution was the technological response to a world-wide food shortage which became threatening in the period after WWII. The Green Revolution transformed farming practice in many regions of the tropics and sub-tropics where the principal food crops were rice, wheat and maize (Freebairn, 1995).

Technology: The projects within the Green Revolution spread technologies that had already existed, but had not been widely used outside industrialized nations. These technologies included pesticides, irrigation projects, synthetic nitrogen fertilizer and improved crop varieties developed through the conventional, science-based methods available at the time. The novel technological development of the Green Revolution was the production of novel wheat cultivars. Agronomists bred cultivars of maize, wheat, and rice that are generally referred to as HYVs or “high-yielding varieties”. HYVs have higher nitrogen-absorbing potential than other varieties. HYVs significantly outperform traditional varieties in the presence of adequate irrigation, pesticides, and fertilizers. In the absence of these inputs, traditional varieties may outperform HYVs. Therefore, several authors have challenged the apparent superiority of HYVs not only compared to the traditional varieties alone, but by contrasting the monoculture system associated with HYVs with the polycultural system associated with traditional ones (Igbozurike, 1978).

Production increases: Cereal production more than doubled in developing nations between the years 1961–1985.Yields of rice, maize, and wheat increased steadily during that period. The production increases can be attributed roughly equally to irrigation, fertilizer, and seed development, at least in the case of Asian rice. Green Revolution techniques also heavily rely on chemical fertilizers, pesticides and herbicides.

Effects on food security: The effects of the Green Revolution on global food security are difficult to understand because of the complexities involved in food systems. The world population has grown by about four billion since the beginning of the Green Revolution and many believe that, without the Revolution, there would have been greater famine and malnutrition. The average person in the developing world consumes roughly 25% more calories per day now than before the Green Revolution Between 1950 and1984. As the Green Revolution transformed agriculture around the globe, world grain production increased by over250% (Spitz, 1987). The production increases fostered by the Green Revolution are often credited with having helped to avoid widespread famine, and for feeding billions of people. There are many claims that the Green Revolution has decreased food security for a large number of people. One claim involves the shift of subsistence-oriented cropland to cropland oriented towards production of grain for exporter animal feed. For example, the Green Revolution replaced much of the land used for pulses that fed Indian peasants for wheat, which did not make up a large portion of the peasant diet (Kindall et.al, 1994). There have been numerous attempts to introduce the successful concepts from the Mexican and Indian projects into Africa. These programs have generally been less successful, for a number of reasons. Reasons cited include widespread corruption, insecurity, a lack of infrastructure, and a general lack of will on the part of the governments. Yet environmental factors, such as the availability of water for irrigation, the high diversity in slope and soil types in one given area are also reasons why the Green Revolution is not so successful in Africa (Clive, 2007).

2.1.3.3) The Role Of Technology In Agriculture

Our current food trajectory is not sustainable. The world's population will climb to over 9 billion in the coming years, with nearly all of the growth occurring in less developed countries of the world where agricultural productivity is relatively low, such as Sub-Saharan Africa and Asia. This population boom will be accompanied by increased strains on our food supply and resources, causing increased pressure on already delicate political and ecological systems, as well as threats to global security. To feed our ballooning population, global food production must increase by an estimated 70 percent, and almost double in developing countries. Moreover, we will need to address both under nutrition and over nutrition, which contribute to poor health outcomes and impose significant costs on our society. As a result, the need has never been greater for innovative solutions that will lead to significant improvements in our food and nutritional security, including greater investment in science and technology. Through these tools and much greater investment in agriculture, we can move toward more sustainably curbing global hunger and malnutrition around the world by dramatically increasing productivity yields, conserving food by substantially reducing postharvest losses and food wastage, giving farmers access to real-time information and services in the field, and even improving the nutritional content of foods (OECD, 2001).

A) Improving the Livelihoods of Farmers and their Families by Producing More and Higher Quality Crops for a Growing Population

Closing the current gap in agricultural productivity will require a significant increase in agricultural yields around the world. This will require seeds that enable crops to withstand environmental and biological stresses, crop protection solutions, modern irrigation practices, mobile technology, fertilizer, and mechanization. **Plant breeding**, the science of optimizing a plant's genetic makeup to produce desired characteristics, can be accomplished through a number of techniques, including hybridization and more complex molecular techniques. Through plant breeding techniques, we can produce higher yielding crops that are better in quality, tolerant to environmental pressures, resistant to pests and diseases, and tolerant to insecticides and herbicides. **Hybridization** involves crossing two or more crop lines to produce hybrid crops with more favorable traits, resulting from combining genes from the selected parents. **Biotechnology** expands the genes available for crop improvement beyond those present in the breeding populations and uses the tools of genetic transformation to bring specific genes to the genetic makeup of the plant. To date, this method has been used to enable crops to tolerate insects, viral diseases, certain herbicides, produce grain with improved nutritional quality, and resist stresses caused by extreme weather. Advances in **crop protection** have been a powerful tool in combating the pests, diseases, and weeds that can devastate crop yields. In total, food crops compete with tens of thousands of species of weeds, nematodes, and plant-eating insects. As a result, even with crop protection products, 20 to 40 percent of food crops are lost each year to pests. These losses occur not only in the fields, but during storage and in the home. Through the use of crop protection products, which include chemical (*e.g.*, insecticides, fungicides, and herbicides) farmers have significantly curbed these losses and increased their productivity yields. These tools enable farmers to produce more crops with less land, making them critical to ensuring a reliable food supply (http://www.globalharvestinitiative.org/index.php/2011-gap-report/).

B) Enhancing the Nutritional Value and Safety of Food to Improve the Health and Wellbeing of People around the World

Technological advancements in food and agriculture are making it possible to improve the health and wellbeing of millions of people worldwide. Malnutrition, defined as both under nutrition and over nutrition, impacts roughly 1 billion men, women, and children. Approximately one in seven people go to bed hungry worldwide. Under nutrition is linked to the deaths of one out of every three children under the age of five in the developing world. Meanwhile, in 2008, over 1.4 billion adults were overweight or obese and an estimated 65 percent of the world's population lives in countries where over nutrition takes more lives than under nutrition (WHO, Obesity and Overweight Fact Sheet, 2012). Consequently, a critical component of global food security will be ensuring not only the production of more calories, but enhancing the nutritional content and health profile of the food the world consumes. As people increasingly migrate to urban areas and away from where food is grown, fortifying processed food will be particularly important. Beyond making the food we eat better, advances in science enable us to preserve foods longer, improving food safety. Nearly one third of the world's food – approximately 1.3 billion tons – is lost or wasted each year (FAO, 2011). In the developing world, a third of food is lost at the production, harvest, post-harvest, and processing phases due to a lack of adequate storage and processing facilities. By contrast, one-third of food in developed countries is wasted by retailers and consumers at the table and in the refrigerator. However, through natural and bio-based ingredients, such as enzymes, cultures, plant extracts, and new preservation techniques, we can reduce food wastage and spoilage significantly in regions without adequate storage and processing facilities, as well as extend the shelf life of food wasted in the industrialized world. For example, emulsifiers and enzymes can be added to bread to keep it fresh for several more days and protective cultures can be added to dairy products to allow them to withstand elevated temperatures and humidity.

C) Contributing to Agriculture Sustainability through Reduced Resource Use

Agriculture's footprint on our ecosystem is substantial. In fact, agriculture consumes 70 percent of our world's water for the irrigation of crops. However, advancements in agriculture technology are an important contributor to a more sustainable agriculture system that promotes continuous improvement and less resource use. Scientists are developing seeds that are better adapted for volatile climates and that are drought resistant, as well as technology that uses less water and improves upon modern irrigation practices. Investment in agricultural innovation is necessary to enable the world to produce more food with fewer resources and less land. There is also the opportunity for more efficient livestock production. Plant-based proteins will be needed as a less resource intensive human food protein source as the population grows and the demand for meat, milk, and egg products increases along with rising incomes, especially in developing countries. Farmers have always looked to new technologies as a way to reduce costs. In addition, higher incomes, greater knowledge and improved communication channels are leading consumers to demand low-cost food of higher quality increasingly produced through organic methods in many countries, with more variety, consistency and year-round availability. At the same time, consumers are increasingly demanding that their food be produced using techniques that conserve natural resources, limit environmental pressures and pay greater attention to rural viability and animal welfare. The process of trade liberalization is widening the sources of supply and the degree of competition. The changing demands are reflected in policies and are powerfully transmitted to farmers by the media, pressure groups, food retailers and processors.

2.2) Empirical Literature Review

2.2.1) Cross Country Empirical Literature Review

In this section attempt is made to summarize countries experience and studies on the response of agricultural TFP shock of the economy wide impact at global level and later provide some new evidence of our own country. These studies have applied methodologies to capture the effect of agricultural TFP on a wide range of the economy different case study (whether developing or developed countries) and have arrived at its own conclusions and policy recommendations. For more than a decade, a large number of theoretical and empirical studies have investigated the total factor productivity (TFP). While the origins of total factor productivity analysis can be traced back to the seminal paper by Solow (1957), developing a production function in which output growth is a function of capital, labor, and knowledge or technology. Technology is Harrods neutral and it is assumed to be exogenous and homogenous across countries. Recent years have seen a surge in both theoretical and empirical studies on TFP (Jintian *et al.* 2009). Agricultural total factor productivity growth would generate increased demand not only for food but also for other industrial outputs and services via intermediate and final demand linkages, foreign exchange savings and reduction in food imports and increase the ability to export. Further, increased agricultural productivity may cause lower and more stable food prices making households better off (Bautista, 1986).

Aruni .G (2012) analysed the effect of agricultural total factor productivity using a computable general equilibrium model (CGE) of Sir Lanka. This paper presents a quantitative assessment of potential macroeconomic, industry level and household level benefits from the increase in productivity of agricultural sectors. The cause of the productivity increase is assumed to be as a result of increase in primary factor productivity. Two simulations (long run and short run) were conducted with this Sri Lankan CGE model based on the ten year development plan[4]. The result of the impacts of simultaneous agricultural total factor productivity improvement was positive real GDP growth in both the short run (0.56%) and the long run (0.73%), increase the real wage in the long run (by 1.12 per cent), increase the level of aggregate employment in the economy in the short run (by 0.04 per cent), improve aggregate real household consumption and exports decrease more than imports in the long run due to a slight depreciation of the exchange rate in the long run (0.47 per cent) compared to short run (1.08 per cent) restores the equilibrium in the trade balance. Finally this paper concluded that increasing agricultural productivity would generate positive economic benefits to the country as targeted in the development framework. Increase in agricultural productivity stimulate the growth of not only agriculture sector but also manufacturing and services sectors (aggregate economy).

Coxhead *et al* (1993) analysed the issue of productivity improvements in agricultural crops due to technological progress in developing countries using computable general equilibrium (CGE) model. The paper which illustrates interactions between upland and lowland agricultural economies and which highlights implications of productivity changes (shock) indifferent sectors for upland soil erosion rates, implied by shifts of land between more erosive food crops and less erosive tree crops. Technical progress in lowland agriculture increases lowland production and land values, increases agricultural sector's output and with it the value of upland land in the production of tree crops, however Upland food production declines and tree crop production expands because of the assumption of erosion from cultivation of tree crops to be lower than for food, they conclude that other things being equal, the green revolution reduced the rate of upland

[4]The development plan identifies improving productivity in the agricultural sector as an important strategy for the development of the country. It targets increases in extent of cultivation and improvement in productivity of different sub-sectors over a ten year period (Ministry of Finance and Planning, 2006).

land degradation and the income of upland dweller were increases due to export more tree product to international market and the income of low land dwellers also increase due to higher demand of upland dwellers food crop and they supply more of it to upland dwellers and generate additional income. Finally the welfare of both dwellers will improve because of technological improvement in agricultural sector and conservation of the soil degradation.

Coxhead *et al* (1995) examine the impact of technical progress in agriculture on income distribution of factor owning household groups, poverty and aggregate welfare in a developing country with open agricultural trade and agricultural trade under restrictions using a computable general equilibrium (CGE) model. Technical progress has taken two main forms: land quality improvement through irrigation, and adoption of new biological and chemical technologies notably modern varieties (MVs) of rice and wheat. The result of the technological change was large poverty reductions among laborers and among landlords and farmers owning land in sector **I (**undergoing rapid technical change) **and** the overall poverty decline and welfare increment produced by the technical progress shock is substantially greater when agricultural trade is unrestricted at constant world price.

Coxhead & Warr (1991) analysed the poverty and welfare effects of Technical Change in agriculture using a computable General Equilibrium (CGE) model for Philippine. The neutral technical change shocks affect poverty in two ways: by raising aggregate income and by altering the distribution of income and expenditure. Relatively large poverty reductions are observed among laborers, owners of the factor specific to the non-tradable sector, and landlords and farmers owning land in the sectors in which the shocks take place. Owners of factors specific to the tradable manufacturing sector, and landlords and farmers in the agricultural sectors not experiencing technical change, experience increased poverty. They show, in a small open economy, technical improvements in farming are likely to benefit poor, especially if the technical change is labor-using, land-saving. It produces a redistribution of income from landlords to laborers.

Arndt et al., (2000) analysed the impact of improvements in agricultural productivity and the reductions in marketing costs in Mozambique using a computable general equilibrium (CGE) model. The paper used the three scenarios:- implementation of agricultural technology improvements, through Hicks neutral total factor productivity increases by 30%, reductions in marketing margins are modeled through scaling down commercial service coefficients by 15% and the last scenarios is the combination of the above two scenarios. The results of the paper showed, in the first scenario, aggregate welfare improvement of 6.8 %, and rise in real GDP by 6.8% and a fall in relative prices significantly in the agricultural sector, a decline in exports by 1.8%, increase in imports by 0.2% in real terms and real exchange rate depreciation of (3.3 %) restores equilibrium in the trade balance. Results of the second scenario indicated aggregate welfare improvement of 4.9%, rise in real GDP by 5%, increase in exports by 6.7%, fall in imports by 0.6% in real terms and appreciation of the real exchange rate (0.1 percent) to restore equilibrium. The increase in welfare in scenario 3 is about 10 percent greater than the sum of the effects of scenarios 1 and 2 run separately. Finally the paper concluded that improvements to the marketing network ensure that increased production following agricultural productivity improvements benefit both farmers and consumers more, as the gap between producer and purchaser prices is narrowed.

Bautista (1986) using a CGE model investigate the economy wide impact of increasing agricultural productivity of Philippine. The paper used 10% increase in total factor productivity in three agricultural sectors (food crops, export crops and livestock and fishing) and in food manufactures sector. The result of the paper indicated a sharp fall in the domestic price of the sectorial product by 28%, 9.61% decline in the domestic price of export crops, a rsie in sectorial production by8.19%, increase in national income by 1.17%, improves the trade balance by $162 million. Based on these results, the author argues that increasing agricultural productivity does not necessary result in reduced rural income but is more likely to benefit urban households. The cause of the productivity increase is assumed to be as a result of technological change and/or improved infrastructure.

Mintewab *et al*. (2011) study Climate change and total factor productivity in the Tanzanian economy using a CGE model. Two different scenarios were used for overall TFP growth: 0.3% annual growth, the rate at which TFP has grown in the entire post-independence period, and 2.3% annual growth, the rate at which TFP has grown in the past 10 years. In the low-TFP (0.3%) scenarios, however, per capita income remained low and, at the end of the study period, was projected to have risen by only about 110. In the high-TFP scenarios, Tanzania becomes a middle-income country. Per capita income nearly doubles each decade.

Elena *et al.* (2001) analyzed the global effects of economic and population growth and the impact of a slowdown in agricultural TFP growth on agricultural and forest resources using global, dynamic computable general equilibrium (DCGE) model. Lower TFP in the agricultural sector relative to the baseline implies higher agricultural and processed food commodity prices. The results suggest that in the case of a slowdown in agricultural productivity South East Asia might face the largest increases in the prices of most crops by 40-47% relative to the baseline, world farm commodity prices rise by about 0.9% per annum on average relative to baseline in the absence of faster TFP growth in agriculture after 2000, loss of productivity in agriculture leads to welfare losses in all regions, any benefits from the slowdown TFP will accrue mostly to landowners not farm workers (because landowner benefited from a higher demand of farmland and incurred a higher rent, conversely farm workers nor benefited more compared to land owner because they must pay a large amount of rent to landowner), adverse environmental effects because it is associated both with reductions in forestland and increases in environmental or ecological damages on remaining forestland.

Cutler *et al*. (2008) study on the Economic Consequences of Productivity Changes: A Computable General Equilibrium (CGE) Analysis. Three types of technological changes have been explored: an increase in labor productivity; an increase in the productivity of capital; and, an overall shift in the production function, or an increase in total factor productivity. The most beneficial total impact to the economy was an increase in total factor productivity in each of the four sectors. The result of the paper: largest increase in household income comes from increased productivity in high services, at US$31.1 million, the manufacturing simulation leads to growth of US$28.8 and leads to the largest increase in tax revenue per new household increases by US$19 890 which is primarily due to a significant increase in property taxes, CPI declines by 0.41%. This paper advised that regional and city policymakers will benefit by understanding how changes in productivity with different sources and sectors, will impact the level of economic activity and the ability of the city to finance expanding demands for police, fire, transportation and recreation services. Estimates of these impacts can aid the policy maker in deciding whether there is value in providing incentives for specific sectors to develop new technologies.

Reid *et al* (2008) Study on the economy-wide impact of Climate change on Namibia's agricultural total factor productivity and fishing sectors on the bases of computable general equilibrium model

(CGE) model. This study used two scenarios for each agriculture and fishing, respectively, combined into four different scenarios. In the first scenario total factor productivity loss of 20% in farms used for livestock production, 10% loss in cereal farms, and 40% loss in subsistence agriculture. In the second scenario total factor productivity loss of 50% in farms used for livestock production, 20% loss in cereal farms, and 80% loss in subsistence agriculture. The result of the paper indicated that, for the above two scenarios, respectively, a 1% and 3.2% loss in GDP & 3.2%, a 1.7% and 11.5% loss in rural wage, 1.1% and 11.5% loss in urban wage. The paper concluded that a combination of two scenarios outcomes for agriculture and fishing will reduce income for all household groups. The relatively richer urban and rural business owners will lose relatively less income than poorer households that work in businesses or on farms, or are involved in subsistence agriculture. Climate change could thus increase inequality in Namibia even further.

De Franco & Godoy (1993) developed a DCGE model to analyses the macroeconomic effects of technological innovations in Bolivian agriculture. The paper were analyzed the effects of agricultural innovations on the Bolivian economy over seven years and the results show that potatoes followed by maize and wheat have a larger impact on the economy than soybeans. The diffusion of a new potato technology unequivocally increases GDP growth rate by 0.3 per cent to 0.8 per cent per year relative to the bench mark economy. A new maize technology increases the bench-mark GDP growth rate by only 0.26 percent per year. The new technologies reduce the real price of the staples by 2.3%, lower household food expenditures, reduced the unemployment by 20%, enhance real wages by 2.1% as long as nominal wages do not decline.

Ehui and Delgado, (2006) Assessed economy-wide impacts of technological change in the agro-food production and processing sectors in sub- Saharan Africa by employing a Computable General Equilibrium (CGE) model. The paper used five scenarios: 3% unit cost reduction in both the processed food crop and meat product sectors, through labor-augmenting technology, 3% unit cost reduction in agro-processing of non-grain food crops and meat products through raw-material-saving, 3% unit cost-reduction in the meat and processed food sectors through cost-reducing technical change in provision of infrastructure services, 3% unit cost reduction through a factor-neutral, output-augmenting technical change in the processed food crop and meat products sectors, and 1.5% Hicks-neutral technical change in the primary production of grains, non-grain crops and animal products. The amalgamated result of the above scenarios was domestic income gain $71.42

million, domestic welfare gain of $4.32 million, increase in overall exports of processed foods and meat products by 2.51 and 3.70 percent, respectively, a fall in output prices for the processed food and meat products by 0.62% and 0.89%, respectively.

Dorosh et.al (2014) looked into effects technical change, market incentives and rural income on Uganda's agriculture using a CGE analysis. The paper used three scenarios:- In simulation 1, 60 % decline in the world price of coffee along with a 20 % decline in coffee production. As a result of this simulation, coffee exports fall by 68.3 % in dollar terms, real exchange rate depreciates by 11.3 %, real producer prices fall by 5%, and real income of farmers fall by 7.1%. Simulation 2 models a doubling of area planted to coffee. The results of the simulation showed a rise in coffee exports (in dollar terms) and production by only 66.9 and 84.9 %, respectively, real appreciation of the Ugandan shilling by 10.3 %, a rise in farmers real income by 1.9%. In simulation 3, total factor productivity (TFP) of crop agriculture is increased by 5 %. The results of this simulation indicates a rise coffee production by 5.2 %, a fall in market prices by 3.6 %, a rise in real consumption among farmers by 2.1%.

Hans et al (2013) study looked into South Africa's economy-wide effects of increased total factor productivity (TFP) on the country's agricultural sector using a DCGE model. It is presented as a pilot analysis of a more detailed investigation of the impacts of enhanced TFP from 0.2 to 0.6 percent on the agricultural sector in South Africa keeping everything else constant. The paper used two policy scenarios, that is, **base scenario,** this scenario was run by projecting the world economy based on the IMF forecasts from 2007 to 2025 (18 years) and enhancement of agricultural TFP by 0.6% (from 0.2% to 0.6%). The result of the paper indicated that prices are anticipated to decrease by almost 1.3% under the base scenario. Under the policy scenario two (enhanced TFP in agriculture only) income levels will increase by a similar 2.4% while prices will experience a decline of 1.3%. The end of the 18 year period under policy scenario two (enhanced TFP in agriculture only), South Africa's income is expected to experience a US$12.2 billion increase over the Base run outcome, growth of real GDP growth rate is expected to average 3.65%, growth rate of unskilled and skilled labor of expected rise at 1.05% and 1.99%, capital growth rate rise by 4.93%, growth rate of Natural Resources to fall by 1.08%. Finally, this paper concluded that enhancement of agricultural TFP will lead to increased growth rate of the real GDP, unskilled and skilled labor, Natural resources, capital, income of household and the welfare of the societies.

2.2.2) Empirical Literatures in Ethiopia

It may be surprising to learn that, there are a few studies that relatively related to attempt to analyze the economy wide impact of technological shock on agricultural sector in Ethiopia using DCGE model.

Lulit et.al, (2016) aims to assess the long run economy-wide impacts of technological change in food staples in Ethiopia with the help of a dynamic sequential computable equilibrium (DCGE) model. This study uses systematic crop growth modeling tools to estimate the productivity improvement from two important staples (maize and wheat) based on prior analysis conducted for promising drought-tolerant and high-yielding maize and wheat varieties being developed for Ethiopian farming systems. Three scenarios are run to analyze the impact of improved technology in wheat and maize production in Ethiopia. The first scenario simulates an increase in total factor productivity (TFP) in wheat production by 3.95%, the second scenario simulates TFP increases in maize production by 7.1%, and the third scenario combines the first two. The finding of the paper indicated the new technology increases wheat output by 2.7% and that of maize by 6.1%, lower wheat and maize prices by 3.2% and 6.6%, the consumer price index falls by 0.4% and 0.9%, real GDP increases by 0.1% and 0.4%, reduction in poverty by 1.1% and 2.4% in the first two scenarios.

Fantu Nisrane, (2012) Growth in Total Factor Productivity in the Ethiopian Agriculture Sector. The paper looked into why agricultural production in Ethiopia grew annually at 9.3 percent while cultivated area expanded at 4.7 percent during the 2003/04-2008/09 period. In other word remaining growth resulted from intensive use of other inputs, increased productivity, increased efficiency, or a combination of these factors. The result of the paper indicate that efficiency grew annually at 4.9 percent between 2003/04 and 2005/06 and that it represented about 84 percent of the average annual change in TFP, (which mainly occurred between 2003/04 and 2005/06), has an important policy implication. This result, together with the findings that efficiency improved with literacy, with application of the extension package, and with advisory services, implies that the efforts made by the government to educate farmers and expand modern production practices may have started paying off. However, the findings that efficiency declined in the remaining period and that TFP stagnated after 2005/06 requires further explanation and analysis that use detailed and longer data.

Lulit et.al, (2012) Public investment in irrigation and training for an agriculture-led development by using a CGE approach for Ethiopia. The study used scenarios on the basis of the five-year national development plan (GTP). In order to boost productivity through the use of improved seeds, fertilizer, small and medium scale irrigation, and investment in human capital, access to credit, as well as switching to higher value crops and multi-cropping are the major areas of intervention in Ethiopia. However the paper's focus is on irrigation and farmers' training in line with the GTP. Three scenarios were run:- 10%, 15% and 25% increase of public investment in farmers' training, 2%, 2% & 4% skilled labor and irrigated land productivity shock The results of combination of the three previous scenarios:-wages increased by 0.2% during the third year and increased by 0.3% for the remaining period. Overall value added increases by 1.2%, overall GDP at market price increases slightly by 0.3%, total exports increase by 1.9%, total imports increase by 0.5%. The paper concluded that a combination of investment targeted towards increasing the skill of farmers combined with an investment in irrigation is more efficient.

Benson et.al, (2012) Assessing the economy wide impact of total factor productivity change of teff, wheat, and maize production in Ethiopia using computable general equilibrium (CGE). The paper developed three scenarios: - 10%, 25%, 50% increase in total factor productivity of teff, wheat, and maize. The result of the paper indicated national increase in production by 18.1%, 1.36% increase in GDP, 3.07% increase in the size of the agricultural sector of the economy, 1.13% increase in the welfare of all household, a fall in poverty headcount by 2%. In summary, the cereal subsector of Ethiopia's agricultural economy offers considerable scope for contributing to the economic transformation of the country. The Teff, Wheat, and Maize Initiatives of ATA are appropriate approaches to realizing some of the potential the sector has to contribute to such a transformation. Policymakers should be sensitive to the possibility that there might be alternative public investments, whether in the agricultural sector or in other sectors, that would provide similar levels of economic growth, poverty reduction, and increased household consumption more efficiently at less cost.

P. Dorosh & J. Thurlow, (2009) uses computable general equilibrium (CGE) model to assess the implications of Accelerated Agricultural Growth for Household Incomes and Poverty in Ethiopia. The study modeling framework was developed and used to examine the contribution of accelerating growth in alternative agricultural crops and subsectors and to assess how Ethiopia can achieve the CAADP target of 6 percent agricultural growth. Three different scenarios were designed for this analysis. That is increase total factor productivity (TFP) of cereals (Simulation 1) by 6.26%, export-oriented crops (Simulation 2) by 6.39%, and livestock (Simulation 3) by 6.81%. These result in wheat production increase from about 4 million tons in the baseline scenario to over 6 million tons in the all agriculture scenario, livestock growth doubles to 6.02%, expansion of coffee production by 0.76%, increase the national GDP growth rate by 6.88%, the manufacturing sector increases by 6.82%, poverty to decline by 4.3%. Overall, however, it is the cereals sector simulation that is most effective in reducing national poverty, because a larger share of poor households depend on cereals for their incomes and because more poor consumers (in rural and urban areas) spend a greater share of their income on cereals and milled grains.

The study by **Diao and Pratt (2007)** focused on which agricultural subsectors are important in Ethiopia's economic growth and poverty reduction and what kind of agricultural and nonagricultural growth is needed to achieve the millennium development goal of halving the incidence of poverty by 2015 using a CGE model. Given a high population density in most of Ethiopia's rural areas, increasing land productivity is the only feasible strategy for improving food security. Under staple crop scenarios (increasing TFP of staple crop by 2.1%) results in rural poverty rate to fall to 37.7%, urban poverty rate falls to 31%, GDP growth of 3.9% per year, and agricultural GDP growth of 3.5% per year. Under export crop scenarios (increasing TFP of export crop by 8.1%) results in economic growth of 3.6% per year, and agricultural growth of 3.4% per year. Combining the above both scenarios of Ethiopia's major agricultural subsectors could induce 5.1% growth per year in the overall economy, and 5.3% growth per year in agriculture. Such growth would reduce the poverty rate by as much 18% points over the business-as usual level, to 27.5% in 2015.

To summarize, the empirical studies so far conducted to analyses the impact of TFP shock on agricultural sector to capture the economy wide effect concentrated (limited) itself on some part of agricultural subsector, in other word which were not aggregately analyzed the change in TFP over agricultural sector at a time rather than analysis the economy wide impact of TFP on agricultural sub-sectors. In addition almost all papers have not statistically estimated the value of agricultural TFP, which is vital for policy simulation; rather they used the value of agricultural

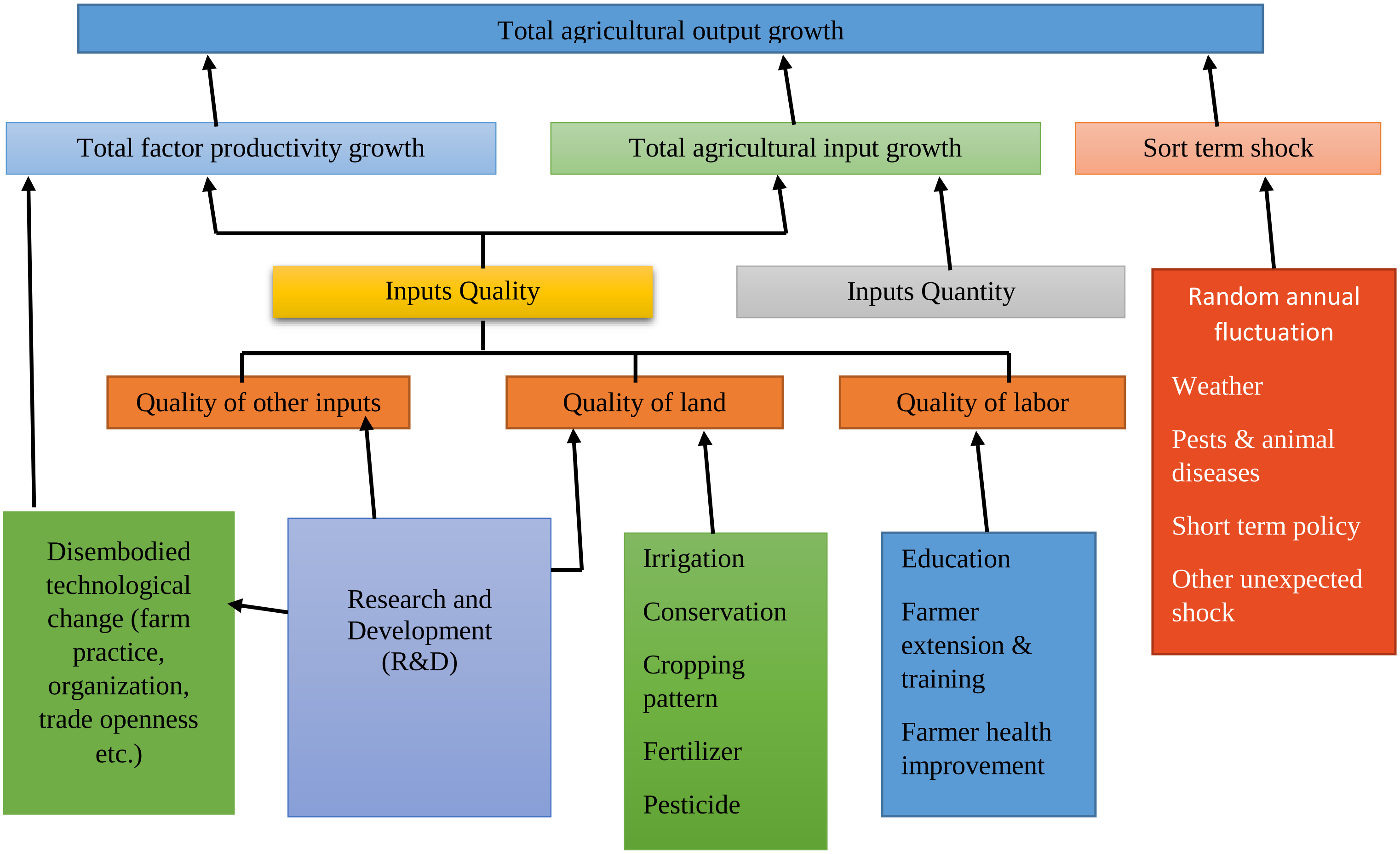
TFP taken from other country studies with similar economic level of development. Notwithstanding in this paper attempts to bridge this gap in the above literature through making:- a) estimate the value of agricultural TFP using panel data estimation techniques, b) analyzing the economy wide impact of technological shock on agricultural sector instantaneously rather than make economic wide analysis on separated agricultural sub-sectors.

2.3) Conceptual Framework

2.3.1) TFP (technology) and Agricultural Output Conceptual Framework Based on Panel data analysis.

Solow (1957) was the first to propose a growth accounting framework, which attributes the growth in TFP to that part of growth in output which cannot be explained by growth in factor inputs like land, labor and capital. Productivity growth is essential to meet the food demand arising out of steady population and economic growth. TFP is a simpler concept than that of technological change and is, therefore, the most common measurement of technical progress. Technical progress has two components: technical change and improvement in technical progress. The former represents improvements in best production practices, while the latter occurs when actual production practices move closer to the existing best practice (Kumar et.al, 2008).

Figure 2. 3 Sources of agricultural output growth

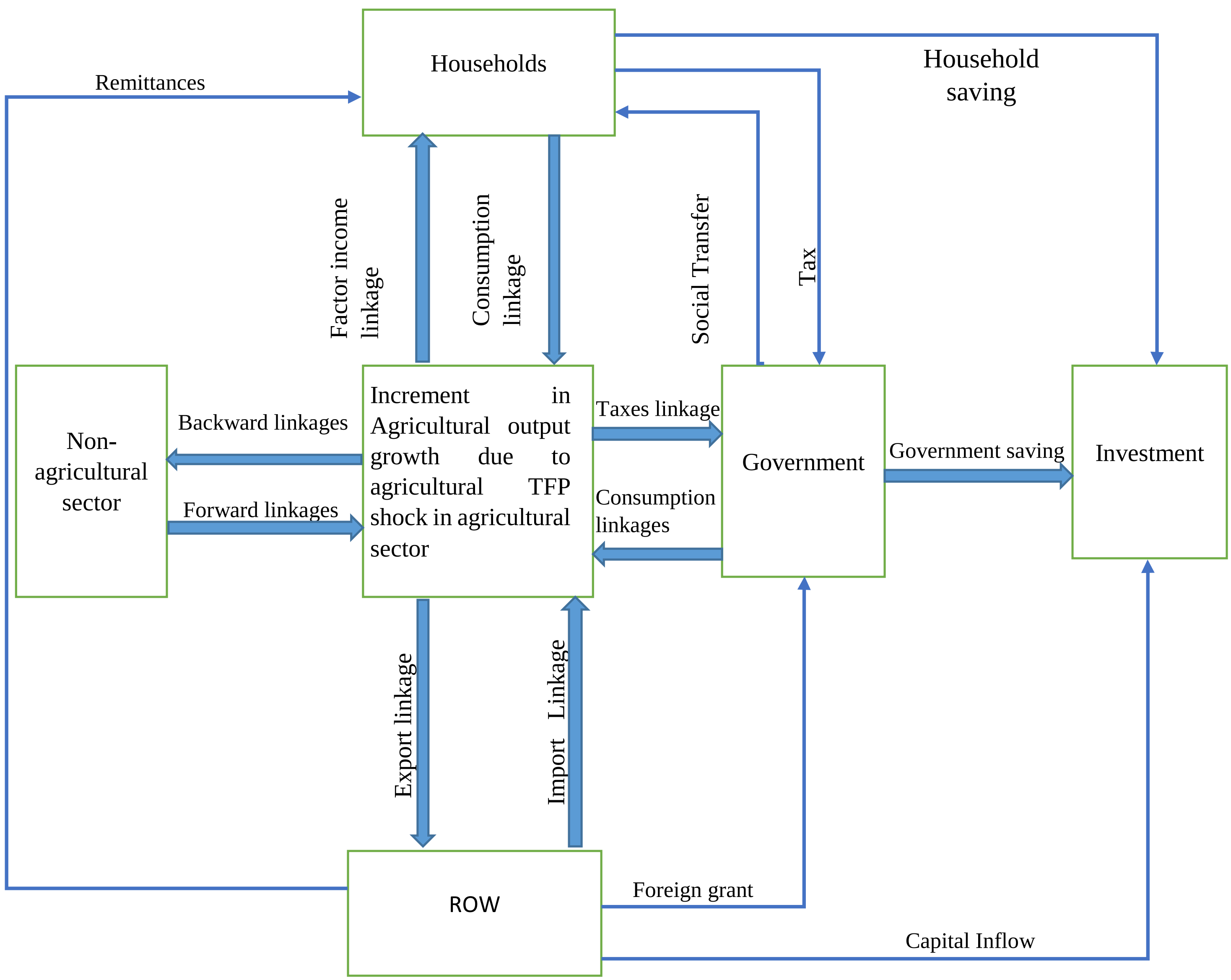


Source: extension of Wang et.al, 2015

As from the above figure the contribution of improved technology is measured as TFP growth, which can be further decomposed into several factors, research and development, extension, education, infrastructure, irrigation, fertilizer, farm practice and so on. The input growth is also influenced by several factors like input-output prices, technological innovations, institutions, infrastructure, policy initiatives, etc. The sources of long-term growth in agricultural output are input growth and TFP growth (fig.2.3). Although output growth can be affected by adverse weather events, pests or animal diseases, business cycles, or other factors in the short term, it often returns to its previous trend over time. The factors causing short-term fluctuations in agricultural output differ from those affecting long-term trends and generally call for different policies. Investments in agricultural research & development results in agricultural include higher yielding crop varieties, better livestock breeding practices, and better farm management practices. This also contribute to amass the agricultural output growth through enhancement in TFP, input growth and disembodied technological (farm practice, organization) change. Agricultural research is required not only to increase agricultural productivity, but to keep productivity from falling. Empowering the labor force through provision of better extension and training, education and health services has a better and prime significant to agricultural output growth over and done with enhance in agricultural TFP and input growth (quality of labor). Therefore, the farmers have knowhow about how to use the existing new technology and able to do their work efficiently while keeping their health safe. On the side of land, due to technological improvement, the land quality will be improved through efficient use irrigation conservation cropping pattern, fertilizer, pesticide will leads to increasing the stock of agricultural output more than before. Finally the amalgamation of the above technological impact will increase the agricultural output growth on the side of total factor productivity and inputs growth.

2.3.2) Agricultural output growth and the Economy Wide (General Equilibrium) Conceptual Framework

Figure 2. 4 the circular diagram of Agricultural output growth and the Economy Wide (General Equilibrium) Conceptual Framework



Source: own computation from differ source

From the above figure, agricultural output expansion due to technological improvement leads to increased demand of factor of production (factor demand linkage) and intermediate inputs from other sector. This higher demand of factor by agricultural sector incurred additional income to the owner of factors (households), then households get additional income than before and increasing its demand for additional consumer goods and service (consumption linkage). Therefore the agricultural sector also supplies its additional output to the market to get income from additional household demand of goods and services. When agricultural production expands, it demands intermediate goods like fertilizers, machinery and transport services. This demand then stimulates production in other sectors to supply these intermediate goods (Backward linkage). In addition expansion in agricultural production increases the demand for intermediate input from abroad which benefit foreign producers (import linkage).When agricultural output expand, then it supply to the domestic market and to the international market. The supply of agricultural output to domestic market stimulate the production of other sector which is used agricultural output as intermediate inputs, example agro-processing (food and beverage), industry, manufacturing industry (forward linkage). Agricultural sectors export the remaining output from domestic demand to international market and get additional foreign currency to the country (export linkage). Government charge a tax from households and sectors, as stated above agricultural output expansion leads to increase in government income because of government charges additional tax on additional output production and sell to agricultural sector (tax linkage). And also the government charge households additional tax from its additional income. The amalgamated effect of additional tax income of the government from households and sectors will increase the consumption demand of the government (consumption linkage), this again stimulate the production of output of the sectors to benefit from additional government demand. The reaming income of household, that is a left over pay to the government (as tax payment) and sector (as consumption expenditure), additional income from ROW (remittance) and government (social transfer) to be saved as household saving. This household saving will be invested by investor (both private and government). The reaming income of government, it is a left over pay to the households (social transfer) , national expenditure (budget) and sectors (subside), additional income from ROW (like foreign grant) and households, sector and enterprises (as tax revenue) to be saved as government saving. This government saving will be invested by investor (both private and government). Finally additional income of household, government, and sector (firms), which is arise from additional output growth in agricultural sector and other sources will increase investment at both government and private level. This will leads to increase national output level, higher employment opportunity, expansion of infrastructure, stabilizing the macro and micro economic problem of the country.

CHAPTER THREE: - METHODOLOGY

To analysis economy wide impact of technological shock in agricultural sector, the paper will use Dynamic computable General Equilibrium model (DCGE) developed by IFPRI. In addition in order to know the determinant factor for technological change (shock), the model will employ panel data analysis to estimate the values of TFP from 2009/10-2016/17. Dynamic computable General Equilibrium model then uses these estimated values for simulation purpose by making scenarios on the estimated values of agricultural total factor productivity (AgTFP).The use of DCGE modelling framework is motivated by the fact that it provides both an economy-wide assessment of policies and a framework in which the workings of policies can be more easily understood, in addition the model incorporates features developed over recent years through IFPRI's research projects. These features are of particular importance in developing countries. Including household consumption of non-marketed ("home") commodities, explicit treatment of transaction costs for commodities that enter the market sphere, and a separation between production activities and commodities that permits any activity to produce multiple commodities and any commodity to be produced by multiple activities (Lofgren *et al*., 2002).

3.1) Data Source

The main data used for this study collected from secondary data source. The secondary data source that is used to estimate agricultural total factor productivity using panel data approach will obtained from public documentation, IMF (international monetary fund), WB (World Bank), Research gate.com and related published and unpublished article, CSA (The agriculture sample surveys), MoFEC, EDRI, ministry of agriculture. And also the secondary database used to calibrate DCGE model is the Ethiopian updated 2009/10 SAM developed by EDRI.

3.1.1) Social Accounting Matrix (SAM)

To analysis the economy wide impact of technological shock on agricultural sector using DCGE model; the method is calibrated based on social accounting matrix database because SAM provides more information of payments and the flows of good and service for a given economy for a given year. A social accounting matrix (SAM) is a wide-ranging of economy set of accounts written in a condensed matrix form in an economy for a given period of time, usually one year. SAM is a square matrix; each account is represented by a row and a column. Each row of the SAM represents the incomings of a sector, factor or institution. The corresponding column represents the outgoings of the sector, factor or institution. The basic issue in constructing SAM is, for each account in the SAM, total revenue or row total equals total expenditure or column total (Lars Bergman, 2003 & Lofgren*et al*., 2002).

According to Ethiopian Development Research Institute (EDRI) SAM have four major types of accounts: activities, commodities, factors of production, and institutions (households, government, the Rest of World and savings-investment account). **The activity accounts** show the value of commodities (goods and services) produced by each activity and the cost of production of the commodities. The rows in this account represent the value of commodities produced by each activity and the columns represent the cost of production of the commodities for payment to intermediate input and payment for usage of factor of production like labor and capital to the household.

Commodity accounts show the aggregate supply of commodities on the row in value terms like: -domestic production, imports, indirect taxes and marketing margins and the aggregate demand for commodities on the column like: -intermediate input use, final consumption, investment demand, government consumption and exports. **Factor account** is an account owned by household and it is the source of income for household (value-added in each production activity) and the factor were distribute to different account category like activities, commodities, factors of production, and institutions as input of production. The row of factor account recorder the income of household from domestic economy and the rest of the world and also the column of factor account recorder the expenditure of household, were they are making payment to domestic economy and the rest of the world. **Institutions accounts** record all income and expenditures of institutions, including transfers between institutions. This account has three sub accounts namely government institutions and the domestic nongovernment institutions which consist of households and enterprises. On household sub-account the row will indicated the payment received by household from different source like safety net assistance, social security paychecks, and pensions from the government; from firm (business enterprise) salary, wage and reward (bonus) from business profit and remittance from the rest of the world. On the other hand the column of household sub account represent the expenditure (a payment) of the household for the consumption of goods and service, for example direct tax, saving, home consumption[5] and market consumption[6]. In the enterprise sub-account the row indicates the recipient, reward and profit of enterprise of their business, like profit, operating surplus, transfers from other enterprises and ROW, whereas the column side of enterprise sub-account records the expenditure or the cost that incurred during business operation and after business operation, example direct tax, payment to factor incomes and saving. Savings of the different institutions and investment expenditures by commodities are given in the savings-investment account.

The government receives income from households, enterprises and the rest of the world in the form of direct taxes, indirect tax, dividend, official transfer payments, grants and development assistance; which are recorded in the row of the governments account. And also the government incurred expenditure like financing recurrent consumption expenditures, transfers to households and the rest of the world and government savings; which are recorded in the column of the governments account. The ROW account contain outflow (payments) of foreign exchange which is payments for imports, factors, transfers to households and the government, including foreign savings (outflow) are represented in the columns and inflow (incomes) of foreign exchange which is collected from sale of export and factors in the rows of the ROW account. The Saving-Investment (S-I) account is a separate account that records the savings of institutions in the rows and the investment expenditures for commodities in the columns. Savings come from households, enterprises, government and ROW and these savings are what is eventually spent (invested) on capital goods (column).

“The first detailed SAM for Ethiopia, based on economic flows in 2001/02, was completed in 2007. The SAM distinguishes 42 production activities, 61 commodity groups, 5 primary factors, 2 household groups, 17 tax instruments as well as aggregate accounts for trade margins, transport margins, government, investment, and the rest of the world. Subsequent to the completion of the

[5]Home consumption, which is activity- based in the SAM appears as household payments to activities, is valued at producer prices. That is, without marketing margins and the sales taxes that may be imposed on marketed commodities (Lofgren *et al.,* 2002).

[6]market consumption which is commodity- based of marketed commodities appears as payments from household accounts to commodity accounts, the values of which include marketing margins and commodity taxes (Lofgren *et al.,* 2002).

2001/02 SAM, an IO table for the same fiscal year was also developed and for the first time submitted and included into the Global Trade Analysis Project (GTAP) Database. In line with GTAP requirements, the IO table obeys all mandatory splits and is provided in the unified format consisting of six arrays, and supports a 39 sector aggregation of the standard 57 GTAP sectors" EDRI, 2009).

The bench mark database used in this study uses the 2009/10 Ethiopia SAM which is produced by EDRI. In order to represent more or less the economy of 2017, we were updating the 2009/2010 SAM to 2017 **without structural change of 2009/2010 SAM** based on the dynamic parameters growth rate path (recalibrate the parameters) from 2010-2017 like labor growth rate, land expansion growth rate, sectorial total factor productivity growth rate, non-capital factor supply growth rates, non-capital sector-specific factor supply growth rates, capital growth rate, population growth rate, government consumption spending, depreciation, land productivity, labor productivity, and capital productivity and etc. First collected and calculated the values of the above parameters and the real GDP growth rate, average sectorial share to GDP and absolute sector growth rate except sectorial TFP from different source like NBE, published literature, MoFEC, IMF, WB, and etc. Then run the base simulation from 2010-2017, after that compare the actual values of real GDP growth rate, average sectorial share to GDP and absolute sector growth rate from 2010-2017 to their value after simulation on the base of 2009/2010 SAM and finally adjusted the gap of the actual value and the value after simulation on 2009/2010 SAM by sectorial TFP. In these study we take on average 2.6% TFP as adjustment factor. SAM is produced in different level of aggregations. It is disaggregated into 113 activities (with 77 agricultural activities by agro ecological zones, AEZs), 64 commodities, 16 factors (by AEZs except capital), and 13 institutions including12 households. The SAM also has 4 different taxes, saving-investment, and rest of the world account show the interaction of different economic agents. It integrates regionally disaggregated agricultural production and income generation for the four main agro ecological zones of Ethiopia (Humid, high land cereals, drought prone and pastoralist zones). Furthermore, for the completion this study further aggregation of SAM has been done. We have eleven aggregated activities and commodities (cereal, cash crop, livestock, agro-processing, chemicals, machinery, food processing, construction, other manufacture, private service, government service); four factors of production (labor, capital, livestock, and land), four type of household(rural poor ,rural non poor, urban poor, and urban non poor), enterprise, government, four tax category (direct tax, import tax, sales tax and other tax), saving-investment balance and rest of the world.

3.2) Methodology

3.2.1) the Econometrics Model

The present paper attempts to analysis the economy wide impact of technological shock on agricultural sector using DCGE model, even though we must estimate the proxy variable for agricultural technological shock, that is, agricultural total factor productivity for the purpose of simulation in DCGE model. Therefore we will "**estimate Agricultural total factor productivity (technology)"**by using linear panel data approach for seven years from 2009/2010-2016/2017 G.C, the reason for using these years' data is to estimate recent shock to address recent past impacts. After addressing the determinants of agricultural total factor productivity and estimate its values, I will proceed to **DCGE model** and running scenarios on the agricultural total factor productivity using the evidence from the above panel data estimation. Panel data can help researchers identify why commodities behave in different ways and how the behavior of single commodities evolves overtime. The advantages of panel data over cross-section or time series as stated by Gujarati, 2003:-

First since panel data relate to individuals, firms, states, countries, etc., over time, there is bound to be heterogeneity in these units. The techniques of panel data estimation can take such heterogeneity explicitly into account by allowing for individual-specific variables. We use the term individual in a generic sense to include micro units such as individuals, firms, states, and countries.

Second Panel data enables us to study more complicated behavioral models. For example, phenomena such as economies of scale and **technological change** can be better handled by panel data than by pure cross-section or pure time series data."

With panel, the most commonly estimated models are probably fixed effects and random effects models**.**

Fixed effects models control for or partial out, the effects of time-invariant variables with time-invariant effects (rid of the unobserved heterogeneity). This is true whether the variable is explicitly measured or not. How it does exactly so varies by the statistical technique being used. In addition the fixed effects model is simply a linear regression model in which the intercept terms only vary over the individual units (Verbeek, 2002).

The FE model is defined as

$$AgTFP_{it} = \alpha_i + \beta_{it}X_{it} + U_{it}$$

Where

α_i :- (i=1…..n) is the intercept for each commodity

X_{it}:- is a vector of independent variables (the determinant of Agricultural total factor productivity)

β:- is an unbiased estimator of the true population parameter

U_{it}:-is a stochastic error term

Assumptions

A) The explanatory variables (X_{it}) is uncorrelated with error term. These conditions implies that **strictly exogenous**.
B) $\boldsymbol{\alpha_i}$ is a random variable possibly correlated with X_{it} *($\boldsymbol{\alpha_i}$does not have to be orthogonal to X_{it})*
C) so repressor X_{it} may be endogenous (w.r.t to $\boldsymbol{\alpha_i}$ but not U_{it})

Random effects models: *a*nother popular approach is to use random effects models. Linear Random effects models are estimated via Generalized Least Squares (GLS). If there are no omitted variables (or if the omitted variables are uncorrelated with the variables that are in the model), in addition no unobserved heterogeneity then a random effects model is preferable to fixed effects because (a) the effects of time-invariant variables can be estimated, rather than just controlled for, and (b) standard errors of estimates tend to be smaller. However, if relevant time-invariant variables (unobserved heterogeneity) have been omitted from the model, coefficients may be biased (Verbeek, 2002).

The RE model is defined as:

$$\boldsymbol{AgTFP_{it} = \mu_t + \beta X_{it} + \alpha_i + \epsilon_{it}}$$

Where

$\boldsymbol{\alpha_i}$ is the between agricultural commodities error term
$\boldsymbol{\epsilon_{it}}$is the within agricultural commodities error term

Assumptions

a) The explanatory variables (X_{it}) is uncorrelated with error term. This condition implies **strictly exogenous**.
b) $\boldsymbol{\alpha_i}$ are purely random factors, independently and identically distributed over individuals.
c) $\boldsymbol{\alpha_i}$ are uncorrelated to the explanatory variables *($\boldsymbol{\alpha_i}$does have to be orthogonal to X_{it}).*

Finally we need to determine which model (fixed effect or random effect model) is appropriate for this study. To address such question depends on the extent to which we can assume individual specific effects (α_i) are uncorrelated with the explanatory variables (X_{it}). Fixed effect model allows the correlation between the explanatory variables (X_{it}) and individual specific effects (α_i), however in random effect model the correlation between individual specific effects and explanatory variables is not allowed. Hausman test could be used to select between fixed and random effect model. The test is based on the null hypothesis that RE is the preferred model against the alternative hypothesis that the FE is the preferred model.

3.2.1.1) Econometric Model Framework

The objective of econometric model analysis is to estimate the agricultural total factor productivity (TFP)[7] by using the responsible factors (determinant variables) for the change of agricultural total factor productivity. Both theoretical and empirical studies have documented the important of TFP for long term growth (Solow 1957. Hence there are many mechanisms to measure the TFP, Kendrick's (1961) arithmetic measure and Solow (1957) geometric index. However in this study the second method of Solow geometric index approach is employed. Solow geometric index approach to measure TFP is though calculating growth accounting equation (residual approach). TFP is a Solow residuals which is the portion of output not explained by the amount of inputs (labor &capital) used in production. The Solow growth model presents a theoretical framework for understanding the sources of economic growth, and the consequences for long-run growth of changes in the economic environment and in economic policy. We start with Cobb-Douglas production function that specifies output at time t (Y_t) as a function of the economy's stock of capital(K_t), labor force(L_t), and the economy's total factor productivity(A_t). The Cobb-Douglas the production function takes the form:

$$Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{(1-\alpha)} -------- 1$$

Where Y_{it} is total output

[7] Agricultural total factor productivity(TFP) as a proxy variable for agricultural technology shock

A is agricultural total factor productivity (AgTFP)

L is labor proxied by the number people engaged in agricultural sector

K is level of physical capital inputs at a time,

α and (1-α) are share parameters of K and L, respectively

i represents agricultural commodity, i.e, i= 1,2,3…..18

t is production year, i.e, t= 1,2,3…..7

If output changes, it can only be because the economy's capital stock, its labor force, or its level of total factor productivity changes.

- ***To calculate TFP based on growth accounting taking the natural logarithm on both sides of equation (1).***

$$lnY_{it} = lnA_{it} + \alpha lnK_{it} + (1-\alpha)lnL_{it} - - - - - 2$$

$$lnA_{it} = lnY_{it} - [\alpha lnK_{it} + (1-\alpha)lnL_{it}] - - - - - 3$$

Or

$$\frac{\Delta Y}{Y_t} = \alpha\frac{\Delta K}{K_t} + (1-\alpha)\frac{\Delta L}{L_t} + \frac{\Delta A}{A_t} - - - - - - -4$$

$$\frac{\Delta A}{A_t} = \frac{\Delta Y}{Y_t} - \left[\alpha\frac{\Delta K}{K_t} + (1-\alpha)\frac{\Delta L}{L_t}\right] - - - - - - -5$$

Where the first term α (ΔK/K) gives the contribution of capital to the growth of output, the second term (1- α)(ΔL/L) gives the contribution of labor to the growth of output, and the third term (ΔA/A) gives the contribution of total factor productivity to the growth of output.

$$g_Y = \alpha g_K + (1-\alpha)n + g_A - - - - - - - - 6$$

Where g_Y The growth rate of total output

g_K The growth rate of capital

n The growth rate of labor force where it change the labor force exogenously

G_T The growth rate of technology where it change the technology exogenously

g_A The growth rate of exogenous technology

$$n = \%\Delta N_{t+1} = \frac{N_{t+1} - N_t}{N_t} \Rightarrow N_{t+1} = (1+n)N_t — 7$$

$$g_A = \%\Delta A_t = \frac{A_t - A_{t-1}}{A_{t-1}} \Rightarrow A_t = (1+G_T)A_{t-1} - -8$$

$$g_K = \frac{K_{t+1} - K_t}{K_t} --------------------- 9$$

$$g_Y = \frac{Y_{t+1} - Y_t}{Y_t} --------------------- 10$$

Finally one can calculate the share (residual) of technological shock on total agricultural outputs as

$$g_A = g_Y - [\alpha g_K + (1 - \alpha)n] ---------11$$

Or, alternatively we can calculate the Total facture productivity of agriculture as

$$Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{(1-\alpha)}$$

$$\frac{Y_{it}}{K_{it}^{\alpha} L_{it}^{(1-\alpha)}} = \frac{A_{it} K_{it}^{\alpha} L_{it}^{(1-\alpha)}}{K_{it}^{\alpha} L_{it}^{(1-\alpha)}} -------- 12$$

$$A_{it} = \frac{Y_{it}}{K_{it}^{\alpha} L_{it}^{(1-\alpha)}} ------------- 13$$

The Determinants of Agricultural Total Factor Productivity

There are many factors literatures that determine agricultural total factor productivity. However, paper used the most relevant determinants of agricultural total factor productivity, which are more related to the case study. These are research and development, extension & training, infrastructure, fertilizer, irrigation, pesticides & herbicide, trade-openness. Productivity measures do not provide any information about the separate role of each of these factors. However, an understanding of the potential sources of productivity growth is important for formulating appropriate policy decisions to increase productivity and social welfare, the expected sign of all variable variables is positive.

Model specification

The econometric model of the determinants of Agricultural total factor productivity (technology) is specified as

AgTFP=F (fertilizer, Irrigation, pesticides, Research and development, extension &training, trade-openness, infrastructure)

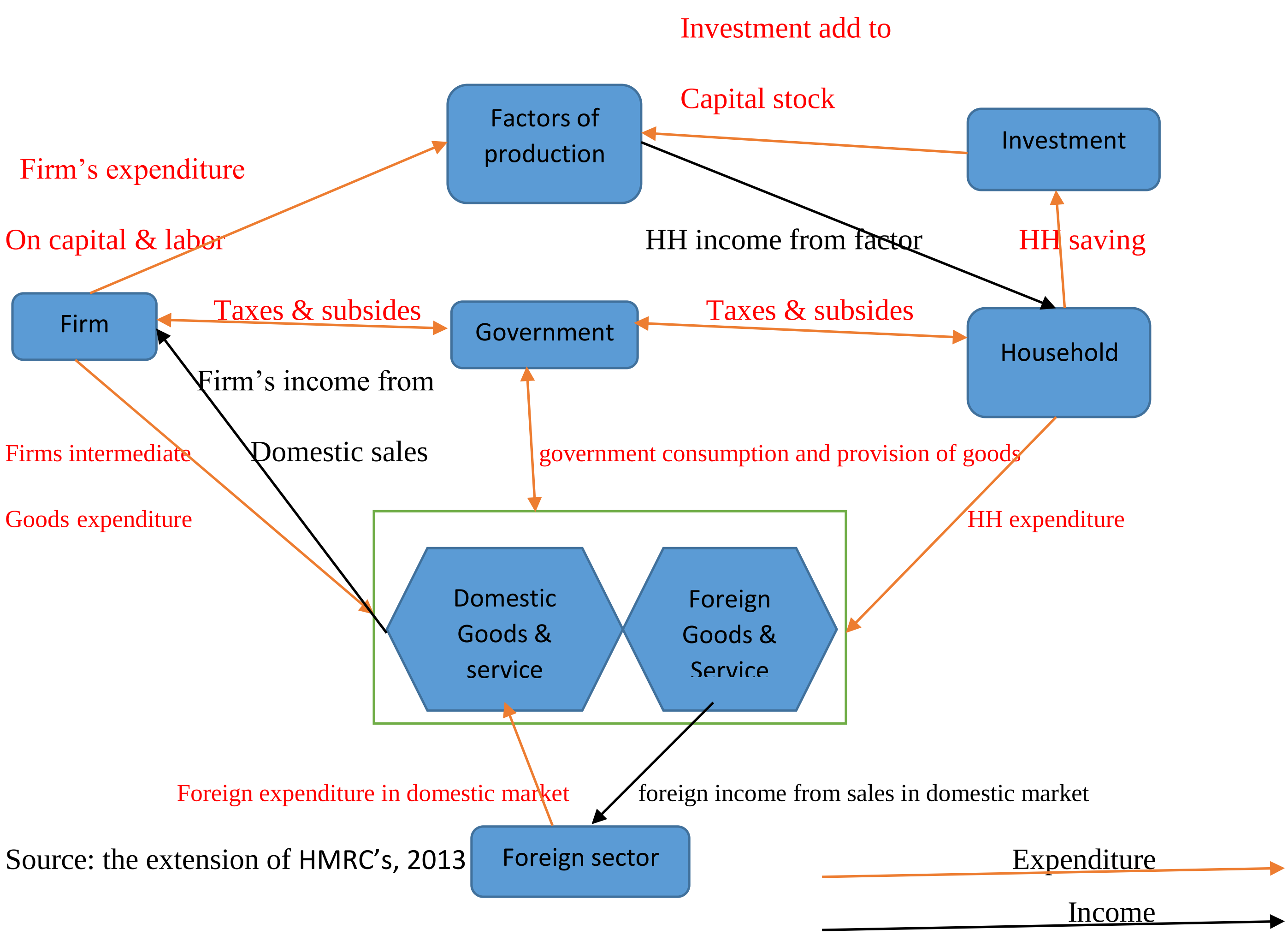
$$\mathbf{AgTFP_{it} = \beta_0 + \beta_1 frt_{it} + \beta_2 irg_{it} + \beta_3 psd_{it} + \beta rd_{it.} + \beta_5 et_{it} + \beta_6 to_{it} + \beta_7 inf_{it} + e_{it}}$$

Where *i* stands for the *i*th cross-sectional unit and *t* for the *t*th time period.
frt - stands for fertilizer
irg – stands for irrigation
psd - pesticides
rd - research and development
et - extension & training
tot - trade-openness
inf – infrastructure

3.2.2) the Recursive Dynamic Computable General Equilibrium (DCGE) Model

To analysis the economy wide impact of technological shock on agricultural sector, these paper used DCGE model. **Dynamic Computable General Equilibrium** are simulations compute numerically the levels of supply, demand and price subject to equilibrium across set of markets over a path of time based on abstract Walrasian general equilibrium structure formalized by Arrow and Debreu. CGE models are a standard tool of empirical analysis, and are widely used to analyze the aggregate welfare and distributional impacts of policies whose effects may be transmitted through multiple markets. Subsequently, commodities are not obviously represented by money in CGE. Nevertheless, in order to make consideration of trade among sectors the amount of different commodities must be comparable by denomination of their values in terms of the value of one commodity (numeracies good), whose price taken as fixed. These means, CGE models solves the numerical equilibrium values of price, supply and demand only based on relative prices (Wing, 2004).The standard CGE model is a set of many nonlinear simultaneous equations with objective functions, which illuminate all of the payments recorded in the SAM and also disaggregation of factors, activities, commodities, and institutions which is founded on SAM (Lofgren, 2002). The most important thing of using DCGE model is to capture the whole inter-dependency of an economy explicitly through market mechanisms like direct and indirect linkage between sectors and consumption and production linkage between economic agents based on restrictive assumptions (Burfisher, 2011).CGE model specifies how economic agent react to each other in order to receive income and spend expenditure based on the circular flow of income. Figure 1 shows CGE representation of the circular flow of income and expenditure, where households receive income (in the form of labor and capital) in the production process in other sector like government, firm and the ROW, and receiving income from the government in the form of transfer (pension) and spend these income on consumption goods which are produced by firms and paying tax to the government and put aside as savings. Firms also receive income from selling goods and services to government, household and ROW and paying tax to the government, paying wage (salary) to household, and market margin. Foreign sector receive income from selling goods and services from other sectors and economic agents, and paying tax, tariff and quota to the government, paying wage (salary) to household and accost on market margin. Government delivers public goods & service and distributes transfer payments to households and firms, and receives taxes, tariff and quota from households, firms and the ROW

Figure 3. 1 circular flows of income and expenditure



Source: the extension of HMRC's, 2013

A CGE model is a large-scale numerical model that simulates the core economic interactions in the economy. CGE models capture the inter-dependencies between the different product markets, factor markets, and public and private sectors in the economy, enabling analysis of how a policy change targeted in one part of the economy will affect the rest of the economy. Hence, this is a useful tool for analysis as policies can often have indirect effects that are difficult to quantify. Although CGE models can simulate future effects of policy changes. Policies are evaluated by comparing the economy between two states of the world. The pre-policy baseline is generated from the base year data and the impact of a policy is estimated by measuring deviations from the baseline following the policy change (HMRC's, 2013).

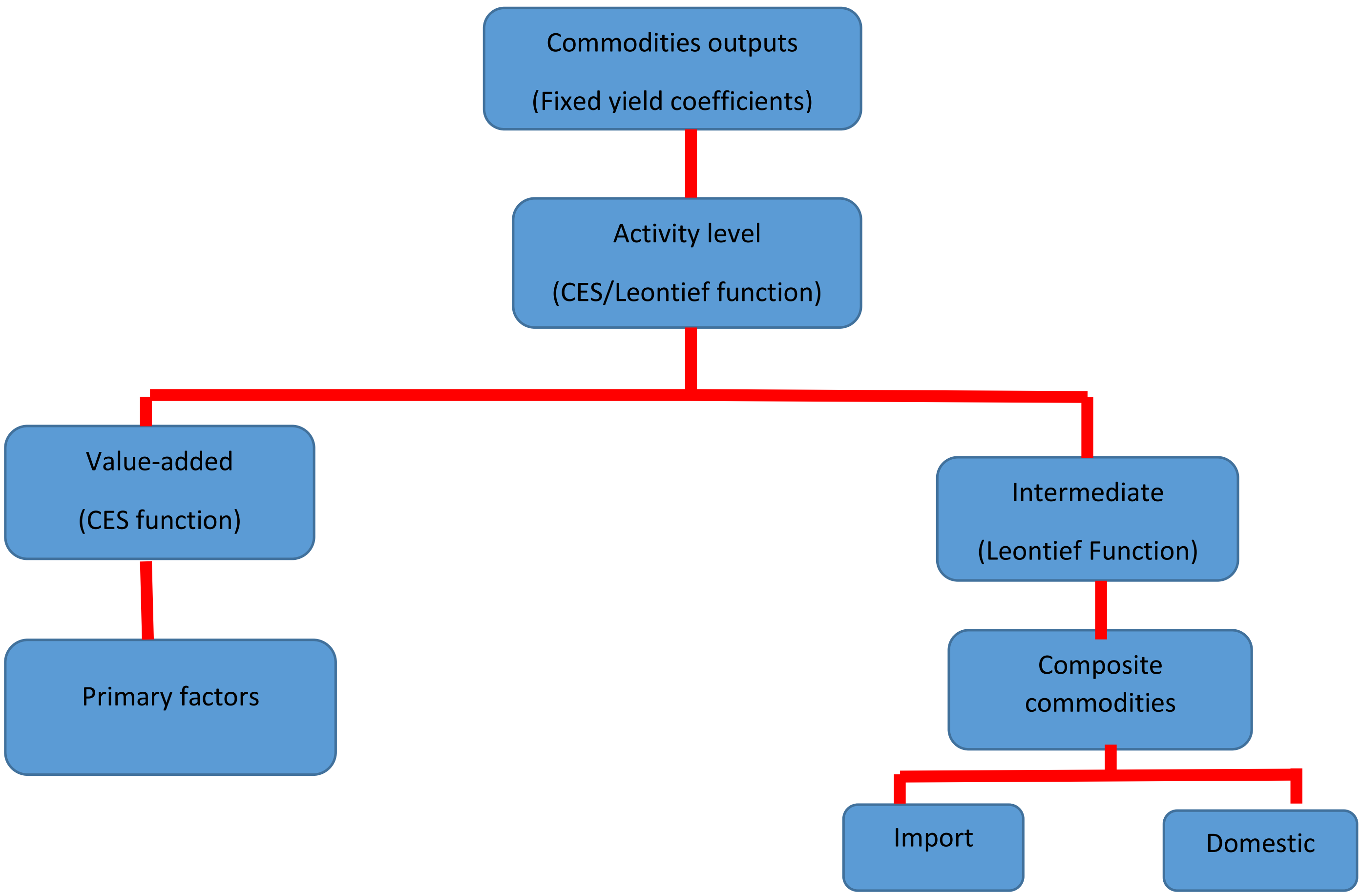
The dynamic computable general equilibrium has two main features, that is, true dynamics (inter-temporal) optimization and sequential (recursive) dynamic CGE model. Sequential (recursive) dynamic CGE model implies that economic agents make their decisions on the basis of past and current information or it is based on adaptive the expectations of their error in the past and correct it based on the trend what they learnt from the past, rather than on the perfect foresight expectations. Sequential (recursive) dynamic CGE model is basically a sequence of static CGE model that are tied between periods by the updating procedure of exogenous and endogenous variables. For instance Capital stock and population (total labor supply) updating endogenously with capital accumulation equation and population growth rate between periods respectively. Inter-temporal dynamic optimization model based on optimal growth theory that economic agent are making their decision based on perfect foresight (forward looking) of the future shock and adjusted their decision currently in order to response (react to) for future policy change and smoothing their current decision like consumption decision. Example household maximize their inter-temporary utility function under budget constraint in order to determine their consumption over time and firm investment decision are the results of cash flow maximization over the whole time horizon (Lofgren and Robinson, 2004). A recursive dynamic model syndicates of a within period (static) module and a between-period (dynamic) module. The within or static period specification tell us the detailed description and outcome of policy change (shock) at a time only or it is restricted to one period and unable to describe the effect of the policy shock over time. It solves the maximization problem of the consumers and the producers based on the prevailing prices (Thurlow, 2004). The between period (dynamic) model addresses the second and subsequent period outcomes through endogenously or exogenously updating of the variables. For example the current period investment could be made a function of the previous period investment and also the current period investments are used for the next period new capital stock, therefore Capital stock could be updated endogenously with capital accumulation equation. Another example could be population updating exogenously by population growth rate and technology also updating exogenously. This paper uses the Sequential (recursive) dynamic CGE model for the reason that economic agents in developing countries are mostly characterized by adaptive expectation rather than forward looking agents.

The simultaneous non-linear and linear equations define the performance of different economic agents like firms wants to maximized their profit (the factors receive income where marginal revenue equals marginal cost based on endogenous relative prices) subject to constant returns to scale technology, with the choice between factors being governed by a constant elasticity of substitution (CES) function. This specification is important to the firms (producer) to make comparison between factors based on their relative price and choose the one whose price is least compared to the other in order to smoothly substituting between available factors so as to derive a final value-added composite. Households also want to maximize their utility subject to constraints. These constraints cover markets (for factors and commodities) and macroeconomic aggregates (balances for Savings- Investment, the government, and the current account of the rest of the world) (Thurlow, 2004).

Figure 2 provides the production technology. The production technologies are either a constant elasticity of substitution (CES) function or a Leontief function of the quantities of value-added and aggregate intermediate input. The CES function may be preferable for particular sectors if empirical evidence suggests that available techniques permit the aggregate mix between value-added and intermediate inputs to vary. Leontief function reflects the belief that the required combination of intermediates per unit of output, and the ratio of intermediates to value added, is determined by technology rather than by the decision- making of producers (Lofgren,2002 & Thurlow, 2004).

The model differentiates among activities and the commodities where each activity produces one or more commodities according to fixed yield coefficients. This distinction allows individual activities to produce more than a single commodity and a single commodity to be produced by more than one activity. Fixed-shares govern the disaggregation of activity output into commodities since it is assumed that technology largely determines the production. These commodities are supplied to the market (Thurlow, 2004).

Figure 3. 2 Production Technology



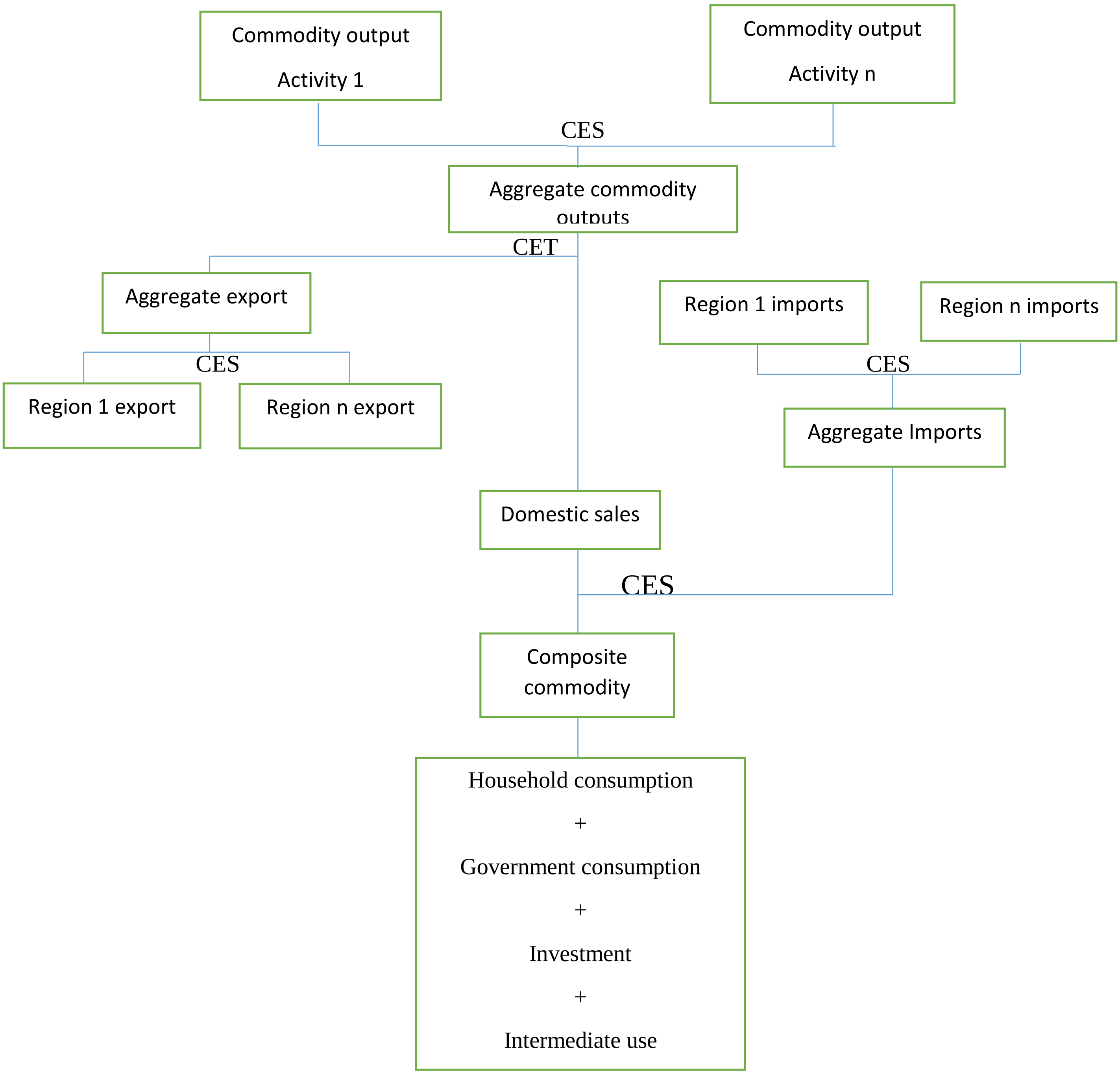
Source: Lofgren, 2002

In the figure below a single commodity to be produced by more than one activity and it is combined to derive aggregate commodity output, which is governed by a CES function. These helps demanders to substitute a single commodity which is produced by different producers, in order to maximize consumption constrained on the price of the supplied of the product. So as to capture any time or quality differences between the production for domestic market and production for foreign market, producers have a possibility of substitution between the production for domestic market and production for foreign market which is governed by a constant elasticity of transformation (CET) function. Commodities that are domestically produced, which could be exported are further disaggregated according to their region of destination under a CES specification and commodities that are domestically produced not exported are supplied to the domestic market. There is also a Substitution between imported and domestic goods both in final and intermediates usage and, governed by CES Armington[8] specification. Lower Armington elasticities implies that there is larger variation between domestic and imported goods, which also vary across sectors. Domestic demander can determined the ratio of imports to domestic goods by their decision on the cost minimization subject to some constraints based on the relative prices of imports and domestic goods. On the bases of region of origin specific tariffs and changes in relative import prices are additionally disaggregated by using a CES function (Thurlow, 2004).“Domestic demand is made up of the sum of demands for household consumption, government consumption, investment, intermediate inputs, and transactions (trade and transportation) inputs” (Lofgren, 2002).

Thurlow (2004) stated that Transaction costs are incurred on exports, imports and domestic sales. These costs are treated as a fixed share per unit of commodity, and generate demand for trade and transportation services. The final composite good, containing a combination of imported and domestic goods, is supplied to both final and intermediate demand. Intermediate demand, as described above, is determined by technology and by the composition of sectorial production. Final demand depends on institutional incomes and the composition of aggregate demand.

[8]This function is also referred to as an Armington function, named after Paul Armington (Armington 1969) who introduced imperfect substitutability between imports and domestic commodities in economic models (lofgren,2002).The use of an Armington specification is justified by the likely heterogeneity of commodities within broad commodity categories, and by the observed two-way trade between domestic country and its trading partners (thurlow, 2004).

Figure 3. 3 Commodity Flows



Source: Thurlow (2004)

3.2.2.1) Within-Period (static) CGE Model

The static CGE model is the one period specification of policy shock on the economy and has four blocks: prices, production and trade, institutions and system constraints. The full explanations of the model equations are provided in the appendix.

Price Block

Due to the assumption of quality variation among products of different origins and destinations of exports, imports, and domestic outputs used domestically, the price system of equation is the most vital one. The price block consists of equations in which endogenous prices are linked to other prices endogenously or exogenously and to non-price model variables.

Import price

This equation involves the import price (PM_c) in LCU (local-currency units), which is the price paid by domestic users for imported commodities exclusive of the sales tax, import price (pwm_c), in foreign currency unit (FCU), tariff adjustment (1+tmc), exchange rate(EXR) in local currency unit per foreign currency unit and cost of trade inputs per import unit (PQC is composite commodity price (inclusive of sales tax and transaction costs), and $icm_{c'c}$is quantity of commodity c' as trade input per imported unit of c).

$$PM_c = pwm_c(1 + tm_c) * EXR + \sum_{c' \in CT} PQ_{c'} * icm_{c'c} \quad ---1$$

Where;
$c \in$ C= a set of commodities (also referred to as c' and C')
$c \in$ CM ($\subset C$) =a set of imported commodities
$c' \in$ CM ($\subset C$) =a set of domestic trade inputs (distribution commodities)

Export price

This equation states that the export price (PE_c) in LCU (local-currency units) is the price received by domestic producers when they sell their output in export markets, export price (pwe_c) in foreign currency unit (FCU), export tax rate $(1 - te_c)$, exchange rate(EXR) in local currency unit per foreign currency unit, and cost of trade inputs per export unit ($PQ_{c'}$) is composite commodity price, and $ice_{c'c}$is quantity of commodity c' as trade input per export unit of c)

In the case of Ethiopia there is no burden of tax on export, therefore export tax rate will be zero. Finally the export price equation will be reformulated as follow

$$PE_c = pwe_c * (1 - te_c) * EXR - \sum_{c' \in CT} PQ_{c'} * ice_{c'c} \quad ----2$$

Where

$c \in CE\ (\subset C)$ = a set of exported commodities (with domestic production)

Demand Price of Domestic Non traded Goods

This price equation differentiates between prices paid by demanders and those received by suppliers, where PDD_c is demand price for commodity produced and sold domestically, PDS_c is supply price for commodity produced and sold domestically, and $icd_{c'c}$ is quantity of commodity *c'* as trade input per unit of *c* produced and sold domestically.

$$PDD_c = PDS_c + \sum_{c' \in CT} PQ_{c'} \cdot icd_{c'c} ------3$$

Where

$c \in CD\ (\subset C)$ = a set of commodities with domestic sales of domestic output,

Absorption

Absorption is total domestic spending on a commodity (imported and domestically produced) at domestic demand prices and does not apply to commodities for which the entire output volume is exported. Absorption is expressed as the sum of spending on domestic output and imports at the demand prices, *PDD* and *PM*. The prices *PDD* and *PM* include the cost of trade inputs but exclude the commodity sales tax.

$$PQ_c \cdot (1 - tq_c) \cdot QQ_c = PDD_c \cdot QD_c + PM_c \cdot QM_c \qquad c \in (CD \cup CM) ---4$$

Where, QQ_c is quantity of goods supplied to domestic market (i.e., composite supply), QD_c is quantity sold domestically of domestic output, QM_c is quantity of imports of commodity, and tq_c is rate of sales tax, $PQ_c \cdot (1 - tq_c) \cdot QQ_c$ is absorption at demand prices net of sales tax, domestic demand price (PDD_c), import price(PM_c).

Marketed output value

For each domestically produced commodity, the marketed output value at producer prices is stated as the sum of the values of domestic sales and exports. Domestic sales and exports are valued at the prices received by the suppliers, PDS and PE, both of which have been adjusted to account for the cost of trade inputs.

$$\mathrm{PX_c \cdot QX_c = PDS_c \cdot QD_c + PE_c \cdot QE_c \quad c \in CX - - - - 5}$$

Where aggregated producer price for commodity (PX_c), aggregate marketed quantity of domestic output of commodity (QX_c), quantity of export (QE_c), export price (PE_c), domestic supply price (PDS_c) and domestic sales quantity (QD_c) are included.

Activity Price

It is the revenue which comes from selling the output or outputs of the activity, mathematically defined as yields per activity unit multiplied by activity-specific commodity prices, summed overall commodities.

$$PA_\alpha = \sum_{c \epsilon C} PXAC_{ac} \cdot \theta_{\alpha c} \qquad \alpha \in A - - - - - 6$$

Where, α is a set of activities, PA_α is activity price or gross revenue per activity unit, $PXAC_{ac}$ is the producer price of commodity *c* for activity α and $\theta_{\alpha c}$ is the yield of output *c* per unit of activityα.

Aggregate Intermediate Input Price

The activity-specific aggregate intermediate input price shows the cost of disaggregated intermediate inputs per unit of aggregate intermediate input and the quantity of input commodity *c* per unit of aggregate intermediate input (not per unit of output).

$$\mathrm{PINTA_\alpha = \sum_{c \epsilon C} PQ_c \cdot ica_{c\alpha} \qquad \alpha \in A - - - - - 7}$$

Where $PINTA_\alpha$aggregate intermediate is input price for activity α and $ica_{c\alpha}$is the quantity of c per unit of aggregate intermediate inputα.

Consumer price index

$$\mathrm{CPI = \sum_{c \epsilon C} PQ_c \cdot cwts_c - - - - - - - - - - 8}$$

Where, $cwts_c$ is weight of commodity c in consumer price index and this equation describes consumer price index (CPI) is calculated by the product of price of aggregated commodity c ($\mathrm{PQ_c}$) and weight of commodity c in the CPI ($\mathrm{cwts_c}$).

Producer Price Index for Non-traded Market Output

$$\overline{\mathrm{DPI}} = \sum_{c \epsilon C} \mathrm{PDS_c} \cdot \mathrm{dwts_c} ---------- 9$$

This section of equation shows how the DPI is determined by the domestic supply price and the weight of commodity c in the DPI ($\mathrm{dwts_c}$). However, once CPI is made supple, DPI is set as numeraire because the model is homogenous of degree zero in price.

Production and Trade Block

The production and trade block consists of four groups:- 1) domestic production and input use; 2) the allocation of domestic output to home consumption, the domestic market, and exports; 3) the aggregation of supply to the domestic market (from imports and domestic output sold domestically); and 4) the definition of the demand for trade inputs that is generated by the distribution process (Lofgren *et al.,* 2002).

Production block

Production takes place by activities that are assumed to act in perfectly competitive market, which maximize their profits subject to technology by taking prices for their outputs, intermediate inputs, and factors as given by the market itself (they are price taker).

There are two alternative specifications, at the top level of the technology nest: the activity level is either a CES value-added or a Leontief function of the quantities for aggregate intermediate input use. This study used Leontief technology at the top level of the technology nesting. The use of Leontief technology (fixed-shares) reflects the belief that the required combination of intermediates per unit of output, and the ratio of intermediates to value-added, is determined by technology rather than by the decision- making of producers (Thurlow (2004)). The reason for using Leontief technology at the top level of the technology nest is to analysis the economy wide-impact of technological shock on agricultural sectors by the amount of value add of factor of production and intermediate inputs using fixed share substitution among them.

Leontief Technology: Demand for Aggregate Value-Added

$$\mathbf{QVA_{\alpha} = iva_{\alpha} \cdot QA_{\alpha}} \quad \boldsymbol{a \in ALEO - - - - - 10}$$

Leontief Technology: Demand for Aggregate Intermediate Input

$$\boldsymbol{QINTA_{\alpha} = inta_{\alpha} \cdot QA_{\alpha}} \quad \boldsymbol{a \in ALEO - - - - - 12}$$

a ∈ALEO(⊂A) = a set of activities with a Leontief function at the top of the technology nest,

Where

$\mathbf{iva_{\alpha}}$- is quantity of value-added per activity unit, and

$\mathbf{inta_{\alpha}}$- is quantity of aggregate intermediate input per activity unit.

$\mathbf{QINTA_{\alpha}}$- is demand for aggregate intermediate input

$\mathbf{QVA_{\alpha}}$-demand for value added

$\mathbf{QA_{\alpha}}$-fixed share of the level of activity

Allocation of domestic output

It is an output transformation function showing that how domestically produced output (QXc) is allocated between domestic sales (QDc) and exports (QEc). Equation (13), below, assumes that there is an imperfect transformation between exports and domestic sales, i.e., there is a CET.

$$\mathrm{QX_c} = \alpha_c^t \left(\delta_c^t \cdot \mathrm{QE}_c^{\rho_c^t} + (1-\delta_c^t) \cdot \mathrm{QD}_c^{\rho_c^t}\right)^{\frac{1}{\rho_c^t}} \qquad c\epsilon(CE \cap CD) \ - - - - - - 13$$

Where
α_c^t - is a CET function shift parameter,
δ_c^t - is a CET function share parameter, and
ρ_c^t - is a CET function exponent.

Export-Domestic supply ratio

This equation specifies how the domestically produced output is optimally distributed between export and domestic sales. Note that this equation assures that an increase in the export-domestic price ratio generates an increase in the export-domestic supply ratio (that is, a shift toward the destination that offers the higher return) (Lofgren *et al*, 2004). The equation is as follow

$$\frac{QE_c}{QD_c} = \left(\frac{PE_c}{PDS_c} \cdot \frac{1-\delta_c^t}{\delta_c^t}\right)^{\frac{1}{\rho_c^t - 1}} \ - - - - - - - - - - - 14$$

Composite supply (Armington) function

The supply of the composite commodity (QQc) is the amalgamation of domestically produced and domestically sold (QDc) and imported commodities (QMc).CES aggregation function captures Imperfect substitutability between imports and domestic output sold domestically in which the composite commodity that is supplied domestically is produced by domestically and imported. When the domain of this function is limited to commodities that are both imported and produced domestically, it is often called an Armington function (Lofgren *et al*, 2004).

$$QQ_c = \alpha_c^q \cdot \left(\delta_c^q \cdot QM_c^{-\rho_c^q} + \left(1-\delta_c^q\right) \cdot QD_c^{-\rho_c^q}\right)^{\frac{1}{\rho_c^q}} ----15$$

Where

α_c^q is an Armington function shift parameter,

δ_c^q is an Armington function share parameter, and

ρ_c^q is an Armington function exponent.

Import-Domestic demand ratio

This equation defines the optimal mix between imports and domestic output. Note that the equation assures that an increase in the domestic-import price ratio generates an increase in the import-domestic demand ratio, that is, a shift away from the source that becomes more expensive (Lofgren *et al*, 2004).

$$\frac{QM_c}{QD_c} = \left(\frac{PDD_c}{PM_c} \cdot \frac{\delta_c^q}{1-\delta_c^q}\right)^{\frac{1}{1+\rho_c^q}} -------- 16$$

INSTITUTION BLOCK

Institution block constitutes income and expenditure of households, enterprises, the government, and the rest of the world. Households receive income from sale of factors to other institutions and transfers from other institutions like from government in the form of pension, from ROW in the form of remittance. Households also spend their incomes on personal consumption, saving, direct tax payment and transfers to other. Enterprises also receive income and transfers from other institutions, and also spend their income on saving (for future investment), tax payment and transfers. The government receives income from taxes collection from other non-governmental institution (household & enterprise) and transfer from other institution like aid from ROW. The government also expends this income for government consumption, saving, transfers to non-government domestic institutions. Incomes for ROW are transfers between the rest of the world and domestic institutions and factors which are all fixed in foreign currency.

Factor income equation

Factor incomes are the total income of each factor in the given economy.

$$\mathrm{YF_f} = \sum_{a\epsilon A} \mathrm{WF_f} \cdot \overline{\mathrm{WFDIST_{fa}}} \cdot \mathrm{QF_{fa}} ------17$$

Where

$\mathrm{YF_f}$= income of factor f,

$\mathrm{WF_f}$= average price of factor f,

$\overline{\mathrm{WFDIST_{fa}}}$= wage distortion factor for factor f in activity a, and

$\mathrm{QF_{fa}}$= quantity demand of factor f form activity a.

Institutional factor income equation

Factor income is split among domestic institutions with fixed shares after settling payments for direct taxes and transfers to the ROW. So, income of each institution from factor payment is the product of share of income of factor to institution and income of factor after transfer.

$$YIF_{if} = shif_{if} \cdot \left[\left(1 - tf_f\right) \cdot YF_f - trnsfr_{rowf} \cdot EXR\right] \quad i \in INSD, f \in F, ---18$$

Where, *i* stands for institutions is an element of INSD (it represents a set of domestic institutions), YIF_{if} represents institutional factor income, $shif_{if}$ represents the share of domestic institution *i* in income of factor *f* , tf_f represents direct tax rate of factor *f* and $trnsfr_{row,f}$ represents transfer from factor *f* to institution *row*.

Income of domestic non-government institution equation

The total income of any domestic non-government institution (households and enterprises) is the sum of factor incomes, transfers from other non-government institutions, transfers from the government and transfers from the rest of the world.

$$\mathrm{YI_i} = \sum_{f\epsilon F} \mathrm{YIF_{if}} + \sum_{i'INSDNG} \mathrm{TRII_{ii'}} + \mathrm{trnsfr_{gov}} \cdot \mathrm{CPI} + \mathrm{trnsfr_{irow}} \cdot \mathrm{EXR} \qquad i \in \mathrm{INSDNG} --19$$

Where, $INSDNG$ stands for domestic non-government institutions, YI_i denotes income of institution i and $TRII_{ii'}$ denotes transfers from institution i' to i.

Household consumption expenditure equation

Households are the only domestic nongovernment institutions that demand commodities for consumption purpose, household consumption expenditure is a residual after payments to direct taxes, savings and transfers and such residual is divided into spending on marketed commodities and home commodities.

$$\mathrm{EH_h} = \left(1 - \sum_{i\epsilon INSDNG} \mathrm{shii_{ih}}\right) \cdot (1 - \mathrm{MPS_h}) \cdot (1 - \mathrm{TINS_h}) \cdot \mathrm{YI_h} \ ---20$$

Where EH_h is household consumption, *h* is an element of a set of households H , $\mathrm{shii_{ih}}$ is share of net income of household *h* to institution *i*, $\mathrm{MPS_h}$ is the marginal propensity to save for household *h* , $TINS_h$ is direct tax rate for *h* ; and YI_h is income of household *h* .

Household consumption spending on marketed commodity

This equation specifies how household consumption spending on marketed commodity is determined.

$$\mathrm{PQ_c} \cdot \mathrm{QH_{ch}} = \mathrm{PQ_c} \cdot \gamma^{m}_{ch} + \beta^{m}_{ch} \cdot \left(\mathrm{EH_h} - \sum_{c'\varepsilon C} \mathrm{PQ'_c} \cdot \gamma^{m}_{c'h} - \sum_{a\epsilon A} \sum_{c'\epsilon C} \mathrm{PXAC_{ac'}} \cdot \gamma^{h}_{ac'h}\right) --- 21$$

Where

QH_{ch} is quantity of consumption of marketed commodity *c* for household *h*,

$\gamma^{m}_{c'h}$ is subsistence consumption of marketed commodity *c* for household *h*,

$\gamma^{h}_{ac'h}$ is subsistence consumption of home commodity *c* from activity a for household *h*, and

β^{m}_{ch} is marginal share of consumption spending on marketed commodity c for household h.

Investment demand equation

The model specifies the investment demand expressed as the base-year quantity multiplied by an adjustment factor which is exogenous in the basic model version implying that investment quantity is also exogenous in the process.

$$QINV_c = LADJ \cdot \overline{qinv_c} - - - - - - - - -22$$

Where, $QINV$ denotes quantity of fixed investment demand for commodity, $LADJ$ denotes investment adjustment factor, and $\overline{qinv_c}$ denotes the base-year quantity of fixed investment demand.

Government consumption demand

It is defined as the base-year quantity multiplied by an exogenous adjustment factor.

$$QG_e = \overline{GADJ} \cdot \overline{qg_e} - - - - - - - - -23$$

Where, QG_e represents government consumption demand for commodity, $\overline{GADJ}$ represents government consumption adjustment factor, and $\overline{qg_e}$ represents the base-year quantity of government demand.

Government revenue

Government revenue is mainly collected from taxes from institutions, import tariff, sales taxes, factor incomes, aid and transfers from ROW.

$$\begin{aligned} YG = & \sum_{i \epsilon INSDNG} TINS_i \cdot YI_i \\ & + \sum_{c \epsilon CM} tm_c \cdot pwm_c \cdot QM_c \cdot EXR \\ & + \sum_{c \epsilon C} tq_c PQ_c QQ_c + \sum_{f \epsilon F} yif_{govf} + trnsfr_{govrow} \cdot EXR - - - - - 24 \end{aligned}$$

Where, YG is government revenue, $TINS_i$ is direct tax rate for institution i, YI_i is income of institution i, tm_c is import tariffs, pwm_c is world price of import, QM_c is quantity of import, $tq_c$is indirect sales tax, $PQ_c$is composite commodity price, $QQ_c$is composite supply, $yif_{govf}$is transfer from institution to the government,$trnsfr_{govrow}$ is transfer from the rest of the world to the government, and EXR is exchange rate.

Government Expenditure

Government spend on consumption of commodities and transfers to other institutions and is fixed in real terms, which means the share of government consumption and transfer not affect by market mechanisms like inflation and it is fixed proportion, it may be changed by political decision. While transfers to domestic institutions are CPI indexed.

$$EG = \sum_{c \epsilon C} PQ_c \cdot QG_c + \sum_{i \epsilon INSDNG} trnsfr_{igov} \cdot CPI$$

Where EG represents government expenditure, PQ_c is composite price, QG_c is government consumption demand for commodity, $trnsfr_{igov}$is transfers from the government to domestic non-government institutions, and CPI stands for consumer price index.

SYSTEM CONSTRAINT BLOCK

The system constraint block specifies model closure rules for the system. **Model closure** is a decision that modelers need to make as to which variables are exogenous and which are endogenous. An example of a closure decision is the modeler's choice between (1) assuming that the economy's labor supply is exogenous, and an endogenous wage adjusts until national labor supply and demand are equal, or (2) assuming that the economy-wide wage is exogenous, and an endogenous labor supply adjusts until national labor supply and demand are equal**.** ***Macro closure*** describes the modeler's decision about which of the two macroeconomic variables will adjust to maintain the identity that of equality of two macroeconomic variables (Burfisher, 2016)**.**

Factor market closures

The factor market closure requires equilibrating factor demand and supply which is dependent on how the relationship between factor supply and wages is defined.

$$\sum_{a \epsilon A} QF_{fa} = QFS_f - - - - - 26$$

Where QFS_f denotes quantities supplied of factor and $QF_{fa}$are factor demanded by activity.The above equation imposes equality between the total quantity demanded and the total quantity supplied for each factor. Land and Capital is fully employed and sector-specific, implying that fixed supply of capital & land; and sector-specific wages adjust to ensure that demand for capital and land equals total supply of capital and land. Unemployment amongst unskilled and semi-skilled, and skilled labor is assumed to be sufficiently large such that economic wide wages are fixed in real terms and labor supply passively adjusts to match labor demand. The intention behind of full employment of land and capital is the fixation of their supply. Skilled, Semi-skilled and unskilled Labor is freely mobile (which is implies that they can be employed in different activities) and unemployed because there is a room for unemployment so its supply is flexible.

Government closure

The government balance enforces equality between current government revenue and the sum of current government expenditures and savings (Lofgren, 2002). This study select the closure for the government account in which tax rates and real government consumption expenditure is held fixed and government savings are flexible. This closure is preferred since it is assumed that changes in tax rates are politically motivated and thus are adopted independent of changes in other policies or economic environment. An alternative for government balance closure: the first one is assumes that direct tax rates of non-government domestic institution (households and enterprises) are flexible and government savings fixed. The general formulation of government balance is given as:

$$YG = EG + GSAV - - - -27$$

Where

YG is government revenue

EG is government expenditure

GSAV is government saving

Current account balance

The current account closure describes equality between the country's spending and its earning of foreign exchange, which is expressed in foreign currency. There are two current account closure method:- the first one is the defaults closure which equilibrate (equal) the country's spending and earning of foreign exchange indicated in the model where fixed foreign savings and flexible exchange rate is the default. The other closure is where exchange rate may be fixed and foreign savings flexed.

The mathematical formulation of the current account balance expressed in foreign currency as follow

$$\sum_{c\epsilon CM} pwm_c . QM_c + \sum_{f\epsilon F} trnsfr_{rowf} = \sum_{c\epsilon CE} pwe_c \cdot QE_c + \sum_{i\epsilon INSD} trnsfr_{irow} + \overline{FSAV} - - - 28$$

Where $\overline{FSAV}$ denotes foreign saving (in foreign currency unit). According to the above equation, import spending plus factor transfers to the ROW must equal the sum of export earning, institutional transfers from the rest of the ROW and foreign savings. This study used the first closure, i.e., fixed foreign savings and flexible exchange rate. The reason that to choose this type of closure is currently in Ethiopia there is currency devaluation in order to adjust or correct current account deficit (export is lower than imports) by increasing export and decreasing imports; and also in fact, Ethiopia has managed floating exchange rate system. Therefore exchange rate adjusts endogenously to make a balance between export and import.

Saving-Investment closures

For saving investment balance the critical difference between the various constraints available for the savings investment balance lies in whether savings are assumed to be investment-driven, so that saving rate adjusts to maintain a fixed capital formation (fixed investment level) or whether investment is considered to be savings-driven, so that the amount of investment (capital formation) is flexible and limited to the fixed saving rate (Thurlow, 2004). Reviewing the Ethiopia economy in this respect, the study picks up the assumption that advocates investment is savings driven, where marginal propensity to save for all non-government domestic institutions is held fixed, while capital formation is made flexible..

Generally the S-I closure rule is stated as: equation

$$\sum_{i\epsilon INSDNG} \overline{MPS}_i \cdot (1 - TINS_i) \cdot YI_i + GSAV + EXR . \overline{FSAV} = \sum_{c\epsilon C} PQ_c \cdot QINV_c + \sum_{c\epsilon C} PQ_c . qdst_c - - - 29$$

Where $qdst_c$ represents the quantity of stock changes. Accordingly, the sum of savings from the government, domestic non-government institutions and the ROW are equated with the sum of fixed investment and stock change. To accommodate for imbalance, the S-I balance also has an optional addition in 'WALRAS' which is valued at zero if the model is in equilibrium (balanced).

3.2.2.2) Between-Period (Dynamic) CGE Model

We discussed the static CGE model in the preceding paragraphs of the paper, which stated the impact of policy change (shock) on the economy at a particular time-period and it is inability to make detailed analysis of the impact of these policy change (shock) over a longer time horizon. For example, the model is unable to account for the second-period effect that changes in current investment have on the subsequent availability of capital. In order to mitigate such problem we employed recursive dynamic CGE model. The recursive dynamic CGE model is the extension of static CGE model which is to account for second, third, fourth and up to N-period considerations by doing updated parameters based on the modelling of inter-temporal behavior and results from previous periods. In the static part factor supply and TFP are exogenous. These variables are updated in the between-period part. In this model, labor supply is determined by population growth exogenously. But capital accumulation is determined the previous period capital stock and investment spending, that is, capital accumulation is determined endogenously. The distribution of the new capital is derived from the initial share of the sector's the aggregate capital income. The current quantity of factor supply and the present TFP are determined by the previous year's quantity of factor supply and the present TFP, respectively. Similarly, the recent government consumption expenditure is updated based on the preceding year's consumption. Sectorial capital accumulation is also updated on the basis of the previous period level of investment.

Capital Accumulation Equation

The process of capital accumulation is modelled endogenously, with previous-period investment generating new capital stock for the subsequent period. Although the allocation of new capital across sectors is influenced by each sector's initial share of aggregate capital income, the final sectorial allocation of capital in the current period is dependent on the capital depreciation rate and on sectorial profit-rate differentials from the previous period. Sectors with above-average capital returns receive a larger share of investible funds than their share in capital income. The converse is true for sectors where capital returns are below-average (Thurlow, 2004).

$$\mathrm{KD}_{\mathrm{i,t+1}} = (1-\delta)KD_{i,t} + IND_{it} - - - - - 30$$

The above equation stated that in each period, capital stock (KD) used in each sector (i) varies with sectorial rate of investment (IND_i) and the rate of depreciation of capital stock (δ).

Labor Force Growth Equation

Population growth is adjusted exogenously with the rate of population growth imposed on the model based on separately calculated growth projections. It is assumed that a growing population generates a higher level of consumption demand and therefore raises the supernumerary income level of household consumption. It is assumed that there is no change in the marginal rate of consumption for commodities, implying that new consumers have the same preferences as existing consumers (Thurlow, 2004).

$$LS_{t+1} = (1 + ng) \cdot LS_t$$

Where,LS_t is the total labor supply and $ng$is an exogenous variable representing population growth rate. In addition factor-specific productivity growth is imposed exogenously on the model based on observed trends for labor and capital. Growth in real government consumption and transfer spending is also exogenously determined between periods, since within-period government spending is fixed in real terms. The remaining part of the dynamic equation were located at appendices part of this study.

CHAPTER FOUR:-EMPIRICAL RESULTS AND ANALYSIS

In this section we begin with the presentation of the estimation result of agricultural TFP and following this, the economy-wide impact of simulation on the shock of agricultural TFP will be described.

4.1) Econometric Result

A panel of agricultural commodities over 7 years from 2003-2009 E.C is used to estimate the agricultural total factor productivity. The analysis done using Stata 13 and Eviews 9 is as presented below.

4.1.1) Pre Estimation

Before run a regression pre estimation tests are conducted to see whether the available data are to be fitted to run a regression or not. In addition after running the regression, to run of diagnostic tests are used to choose the preferred model.

a) Stationary test

Non-stationary time series data has often been regarded as a problem in empirical analysis. Working with non-stationary variables may lead to spurious regression results, from which further inference is meaningless. Hence, the first step in time series econometric analysis is to carry out unit root test on the variables of interest. The test examines whether the series of interest is stationary or not. To conduct the test, the conventional Levin, lin, chu test are used with and without a trend**.**

Hypothesis ***H_0: non stationary (unit root)***

H_a: stationary (no unit root)

Decision: - accept H_0 if t-calculated less than t- tabulated in absolute value however reject H_0 otherwise

Accordingly we present the results of the Levin, lin, chu test in the following table.

Table 4. 1 Unit Root Test

No	Variable Name	t- statistic[9]	p-value
1	Agricultural total factor productivity	-7.48561	0.0000
2	Fertilizer	-9.96656	0.0000

[9] It should be In absolute value term

3	Infrastructure	-18.9664	0.0000
4	Irrigation	-4.61098	0.0000
5	pesticide	-2.06839	0.0193
6	Research and development	-22.2021	0.0000
7	Training and extension	-16.8677	0.0000
8	Trade openness	-17.7008	0.0000

Source: own computation using e-view 9

According to Levin, lin, chu test, since all the P statistics are smaller than critical value we can reject the null hypothesis that all panels are non-stationary. As shown in above the table all variables are stationary at 5% level of significance. After confirming the stationary of our variables estimation of the model is made as follows.

b) Test For Model Selection Between Fixed Effect and Random Effect Model

To recall, the main objective of this part of this paper was to estimate the value of agricultural total factor productivity in agricultural sector. With this interest we have developed two types of model namely the fixed effects and random effects model whose definition and intuitive explanations are given in more detail previously in the methodology section. Whether to treat the individual effects α_i as a fixed or random is not an easy question to answer. To decide between fixed or random effects we can run a Hausman test where the null hypothesis is that the preferred model is random effects against the alternative of the fixed effects.

Hypothesis H_0: random effect is appropriate
H_1: fixed effect is appropriate

```
          b = consistent under Ho and Ha; obtained from xtreg
       B = inconsistent under Ha, efficient under Ho; obtained from xtreg
  Test:  H0:  difference in coefficients not systematic
```

chi2(7) = $(b-B)'\{\hat{v}ar(b)-\hat{v}ar(B)\}^{-1}(b-B)$

= 91.73

Prob>chi2 = **0.0000**

$\hat{v}ar(b)-\hat{v}ar(B)$ is not positive definite)

Therefore the P value is less than 5% then I reject the null hypothesis. Thus, fixed effect model is the most appropriate model.

The fixed effect model of agricultural total factor productivity

----

agtfp	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
frt	2.800851	.2876704	9.74	0.000	2.23019	3.371511
psd	-2.881551	.7059527	-4.08	0.000	-4.281971	-1.481131
irg	-.0600163	.0061211	-9.80	0.000	-.0721588	-.0478737
rd	5.796523	1.832752	3.16	0.002	2.160836	9.432209
te	4.709384	2.243506	2.10	0.038	.2588723	9.159896
to	-.0380668	.0157293	-2.42	0.017	-.0692694	-.0068641
inf	.0393121	.0282578	1.39	0.167	-.0167437	.095368
_cons	-4209.045	1818.514	-2.31	0.023	-7816.488	-601.6027
sigma_u	1823.8908					
sigma_e	34.073497					
rho	.99965111	(fraction of variance due to u_i)				

```
F test that all u_i=0:     F(17, 101) =     5.57             Prob > F = 0.0000
```

4.1.2) Post Estimation Test

To maintain the data validity and robustness of the regresssion result of the research, the basic classical linear regression model (CRLM) assumptions for panel data analysis must be tested for identifying any misspecification and correcting them so as to augment the research quality (Brooks, 2008).

a) Test for Heteroscedasticity

The condition of classic linear regression model implies that the error term of the regression model should be homoscedasticity. This means that the variance of the error term should be constant and same. Variance of residuals should be constant otherwise, the condition for homoscedasticity would be violated. We may recall that OLS makes assumption that variance of error terms must equal that is the variance of the error term is constant (Homoscedasticity). The problem of Heteroscedasticity arises from the violation of different assumptions, misspecification and omitted variables. If there is Heteroscedasticity the OLS estimator no longer BLUE.

Hypothesis H_0: homoscedasticity

H_1: hetroscedasticity

```
Modified Wald test for group wise heteroskedasticity in fixed effect regression
model
```

```
chi2 (18)  =   11902.82
Prob>chi2 =      0.0000
```

The Heteroscedasticity test for this study (Wald test for Heteroscedasticity: test value: 11902.82; p-value: 0.000) shows that problem of Heteroscedasticity is present. The null hypothesis (homoscedasticity) has to be rejected in favor of the alternative hypothesis of Heteroscedasticity. In order to correct for Heteroscedasticity and obtain robust standard errors the option 'robust' is used to obtain heteroskedasticity-robust standard errors (also known as Huber/White or sandwich estimators).

b) Test for serial autocorrelation

Ignoring serial correlation when it is present results the result in still consistent but inefficient estimates of the regression coefficients and biased standard errors. So in order to increase the efficiency of this model autocorrelation has been tested using Durbin Watson test and Wooldridge 2002 test.

```
xtserial agtfp frt psd irg rd te to  inf
Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
    F(  1,      17) =      1.393
           Prob > F =      0.2542
```

According to Wooldridge test we fail to rejects the null hypothesis no first order autocorrelation because the estimated p-value of the test is larger than the nominal level of significance of 5% and 10%.

c) Test for cross-sectional dependence/contemporaneous correlation

Peasaran CD (cross-sectional dependence) test is used to test whether the residuals are correlated across entities. Cross-sectional dependence can lead to bias in tests results (also called contemporaneous correlation).

Hypothesis H_0: residuals are not correlated

H_1: residuals are correlated

```
Pesaran's test of cross sectional independence =     1.814, Pr = 0.07
Average absolute value of the off-diagonal elements =     0.408
```

According to Pesaran's test we also fail to reject the null hypothesis (p-value 0.07 is greater than the the nominal significanc level of 0.05 or it is not significant at 5% that says residuals are not correlated.

d) Test for Multicollinearity

Multicollinearity indicates a linear relationship between explanatory variables which may cause the regression model biased. If an independent variable is an exact linear combination of the other independent variables, then we say the model suffers from perfect collinearity, and it cannot be estimated by OLS. When independent variables are multicollinear, there is overlap or sharing of predictive power. This may lead to the paradoxical effect, whereby the regression model fits the data well, but none of the explanatory variables (individually) has a significant impact in predicting the dependent variable (Gujarati, 2004).

	agtfp	frt	psd	irg	rd	te	to	inf
agtfp	1.0000							
frt	0.2629	1.0000						
psd	0.0622	0.1136	1.0000					
irg	0.2163	0.0973	0.0596	1.0000				
rd	0.2328	-0.0003	-0.0044	-0.0066	1.0000			
te	-0.1436	-0.0024	-0.0095	-0.0011	-0.4737	1.0000		
to	-0.0620	0.0117	0.0493	0.0409	0.1441	0.4833	1.0000	
inf	-0.0089	0.0027	0.0164	0.0057	-0.2771	-0.4250	-0.2148	1.0000

The Pearson correlation, which varies between -1 and 1, if the p-value is 0, there is no linear correlation, and if the p-value is -1 or 1 we have a perfectly negative or positive relationship between the variables. According to Cooper and Schendlar (2003) and Lewis-Beck (1993) since there is no correlation above 0.8, it can be concluded in this study that there is no problem of multicollinearity, thus enhanced the reliability for regression analysis. In addition, careful observation of the pair wise correlation coefficients will be provided and if this coefficient is below

0.8 suggesting that our data set does not suffer from severe multi co linearity problem (Gujarati, 2004).

e) Test for Endogeneity

A standard problem in cross-section empirical work is the potential endogeneity of right hand side (RHS) variables. If any of the RHS variables in the equation are correlated with the error term that variable is considered econometrically "endogenous" and OLS may yield biased and inconsistent coefficient estimates, Baier and Berg strand (2007). The 2SLS estimator is less efficient (i.e. larger variance) than OLS when the explanatory variables are exogenous. Therefore, it is important to test for endogeneity test, in order to avoid using an IV estimator the most famous test is Hausman (1978). If there is no endogeneity, it is more efficient to use OLS. If there is endogeneity, OLS is inconsistent and so 2SLS is the best alternative. In this study two stage least square (2sls) method was used to test for the presence of endogeneity.

Hypothesis H_0: variables are exogenous

H_1: variables are endogenous

```
-------------+----------------------------------------------------------------
         frt |  -.0002258   .0058977    -0.04   0.969    -.011785    .0113335
         psd |   .0088065   .0145601     0.60   0.545   -.0197308    .0373438
         inf |   .0410821   .0366132     1.12   0.262   -.0306785    .1128427
         irg |    .001404   .0054527     0.26   0.797   -.0092831    .0120911
          rd |   .0602568   .0238842     2.52   0.012    .0134447    .1070689
          te |   3.137331   2.873879     1.09   0.275   -2.495368     8.77003
          to |  -.0292054   .0205025    -1.42   0.154   -.0693895    .0109787
       _cons |  -2456.117   2315.581    -1.06   0.289   -6994.573    2082.338
------------------------------------------------------------------------------
Instrumented:  frt
Instruments:   psd inf irg rd te to lfrt
. estat endogenous
  Tests of endogeneity
  H0: variables are exogenous
  Durbin (score) chi2(1)          =  .995178  (p = 0.3185)
  Wu-Hausman F(1,116)             =  .930937  (p = 0.3366)
```

According to both Durbin and Wu-Hausman test we also fail to rejects the null hypothesis (p-value 0.3185 and 0.3366 is greater than the critical value 0.01, 0.05 and 0.10 or it is not significant at 1%, 5% and 10%) that says all explanatory variables are exogenous[10].

4.1.3) Interpretation of the Variables

Fixed effect estimation result of agricultural TFP with Heteroskedasticity-robust standard errors.

agtfp	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
frt	2.800851	.4872886	5.75	0.000	1.772762	3.82894
psd	-2.881551	.470496	-6.12	0.000	-3.874211	-1.888891
irg	-.0600163	.0101274	-5.93	0.000	-.0813832	-.0386494
rd	5.796523	1.555482	3.73	0.002	2.514743	9.078302
te	4.709384	1.422046	3.31	0.004	1.70913	7.709638
to	-.0380668	.0152813	-2.49	0.023	-.0703075	-.005826
inf	.0393121	.0244538	1.61	0.126	-.012281	.0909052
_cons	-4209.045	1094.412	-3.85	0.001	-6518.052	-1900.039
sigma_u	1823.8908					
sigma_e	34.073497					
rho	.99965111	(fraction of variance due to u_i)				

From the above fixed effect estimation result, we have seen that out of seven explanatory variables six of them significantly affect agricultural total factor productivity. Fertilizer is positivity and significantly affect agricultural total factor productivity. Fertilizer is an important factor of modern intensive agricultural practices. Appropriate use of fertilizer leads to highest output and increasing total factor productivity within the existing factor of production or without further increment in the amount of inputs like land and labor. And also fertilizer make faster the growth of crops and plants in addition increasing their yield quantities. Increase in the application of fertilizer use by one unit would induce the agricultural TFP to increase by 2.8. However, when we use fertilizer we should apply the optimal level per hectare and type of crop. Excessive application of fertilizer

[10] For the remaining variables see the appendixes part

may result in reduced production due to harm caused to crops and plants. Use of fertilizer has been found a positive significant determinant of agriculture TFP in a number of studies like Sabir and Ahmed (2003), Ashenafi (2012) and Azhar (1991). Pesticide also significant and negative effect on agricultural total factor productivity. Pesticide may not has one to one relationship to agriculture TFP, which means the use of pesticide has its own limit (optimal) amount of litter per hectare, type of chemical for what type of crops, taking into account the neighbor farm land, livestock and human. However, fails to handle such preconditions may be leads to reduction in the agricultural total productivity. Irrigation has negative significant impact on agricultural total factor productivity which may be due to over cultivation of land with irrigation and rainy season without proper land management mechanism like restoring the cultivated land after harvesting through organic (animal dung) and chemical fertilizer (DAP). These leads to gradual loss of soil fertility and may have a negative impact on agricultural total factor productivity. Research and development has positive and significant effect on agricultural TFP. Public funding for agricultural research is an important factor which affects the development of agriculture through increases in the stock of knowledge, which either facilitates the use of existing knowledge or generates new technology. The results of agricultural research include higher yielding crop varieties, better livestock breeding practices, and better farm management practices. Agricultural research is required not only to increase total factor productivity, but to keep total factor productivity from falling. For example, yield gains for a particular plant variety tend to be lost over time because pests and diseases evolve that make the variety susceptible to attack. Thus, a large share of agricultural research expenditures is devoted to maintenance research. Private agricultural research is mainly performed by manufacturers of farm machinery and agrochemicals, and by food processors. Public agricultural research is performed in national agricultural experiment stations and other universities. Research & Development has positive effects on agricultural total factor productivity. Many studies generally found a strong contribution of R&D to agricultural TFP growth like Griliches and Lichtenberg, 1984; Coe and Helpman, 1995; Griliches, 1998.. Increase in government expenditure on research and development by one unit would induce the agricultural TFP to increase by 5.7. Training and extension also have positive and significant effect on agricultural TFP. Agricultural extension system aims to reduce the time lag between development of new technologies and their adoption. Extension agents disseminate information on crops, livestock, and management practices to farmers and demonstrate new techniques. They also directly consult with farmers on specific production and management problems. Unlike research, it is reasonable to assume that extension has an immediate effect on total factor productivity. Education also speeds the rate of adoption of new technologies among farmers. Better educated farmers are more able to assess the merits of innovative technologies, and adopt them quicker than non-educated farmers, of and successfully adapt a new technology to their particular situations. Education process increases the ability of the farmers for information processing and allow proper choice and utilization of new technologies. Thus, people with complete agricultural education have usually better knowledge concerning new technologies and more reasonable ways of combining available resource, and therefore are able to improve their agricultural total factor productivity. Increase in government expenditure on extension and education by one unit would induce the agricultural TFP to increase by 4.7. Studies by Benhabib and Spiegel, 1994 and Makki, et.al, 1999 found a strong contribution of education and extension to agricultural TFP growth. Finally the impact of trade openness on agricultural total factor productivity is negative and significant. This may be due the fact that in an open economy, any trade partner can have access to export their commodities including agricultural commodities to domestic market. This may leads to increasing not only stock of supply of agricultural commodity but also better quality than the existing domestic commodities in the domestic market. Because of this domestic consumer shift their preference to the imported commodities and decrease demand of domestically produced commodities, which will in turn decrease the price of domestic output. Finally the domestic producer will decrease their income and lowering domestic agricultural total factor productivity. Studies by Majeed et.al (2010), Unel 2003 and Tsl 2003 found that trade openness have a negative impact on agricultural total factor productivity.

4.2) Simulation Specification and Results

4.2.1) The Benchmark Structure of Ethiopian 2009/2010 SAM Characterization

A SAM is a set of accounts written in a condensed matrix form. SAM, which is a representation of an economy for a particular year, is the main database used to calibrate a CGE model and the SAM provides insight into the sectorial and institutional structure of the economy such as the total value added called GDP and other macroeconomic Variables. GDP can be measured by Adding the value added at each stage of production process (Value add approach), adding income throughout the economy (Income approach), and adding the expenditure from all sectors of the economy (expenditure approach). Ethiopia is an agrarian economy for which agriculture contributes 49 percent of total GDP at factor cost followed by services which account for 41 percent. The least is contributed by industry sector which accounts for only 10 percent.

Table 4. 2 Summarize the GDP at factor cost at base year

GDP at Factor Cost		
sector	Value of GDP in billion birr	Percentage of share of GDP
Agriculture	174.25	49
Industry	36.2	10
service	144.55	41
Total GDP at factor cost	355	100

Source: Author's Compilation from SAM for Ethiopia 2009/10 Developed by EDRI

In the production process different factors were used to produce goods and service. Those factors are: labor, land, livestock and capital. Different sector have different characteristics and use different factors depending up on their nature. Below are disaggregated factors of production used by each sector during the production. Accordingly agriculture is labor intensive by employing 52.44% of total labor engaged in production and agriculture is the only sector used livestock and land in production process and use 11.22% of capital engaged in production. Industry uses only 10% and 16.93% of labor and capital engaged in production respectively, which means industry use more intensively capital than labor relative to agricultural sector. Lastly service sector employ 37.49% and 71.84 % of labor and capital is most capital intensive technology during 2009/10. Below is the summary of disaggregated factors of production and their share in to their own total.

Table 4. 3 Summary of Factors of Production with Their Respective Percentage Shares

Sector				
Factor	agriculture	industry	service	total
Labor	91.24(52.44%)	17.51(10.06%)	65.24(37.49%)	174(49.0%)
Land	39.76(100%)	0	0	39.76(11.2%)
Livestock	30.85(100%)	0	0	30.85(8.7%)
Capital	12.38(11.22%)	18.68(16.93%)	79.25(71.84%)	110.32(31.1%)
Total	174.23(46.63)	36.19(9.79)	144.49(43.59)	355

Source: Author's Compilation from SAM for Ethiopia 2009/10 Developed by EDRI

Now proceed to macroeconomic variables including GDP at market price[11], Private consumption, Government consumption, gross capital formation, export, import, domestic saving, foreign saving, trade balance, gross output and total demand. Table blow summarizes the macroeconomic variable adjusted from Social Accounting matrix for Ethiopian economy 2009/10.

From the table below GDP at market price valued at 385 billion birr, of which 338.4 is household consumption, 32.5 is government consumption, 87.3 for investment demand and 74.8 trade deficit. While household consumption accounts for 87.9 percent of GDP, government consumption accounts for 8.5 percent of the economy and 23% for investment demand. Investment demand fully financed by both domestic and foreign saving (88.6=66+22.6), trade deficit balanced (financed) by government and household transfer from ROW(-74.8=74.8).

Table 4. 4 Summary of Macroeconomic variable and percentage Shares to GDP

Macro variables	Value in billion birr	Percentage share of GDP
GDP at market price	385	100
household consumption	338.4	87.9
Government consumption	32.8	8.5
Investment demand	88.6	23
Net export (trade deficit)	-74.8	19.4[12]
Import	126.41	
Export	52.13	
Domestic saving	66	
Foreign saving	22.6	
Direct tax	6	
Indirect tax	30	
Household and government transfer from ROW	74.8	

Source: Author's Compilation from SAM for Ethiopia 2009/10 Developed by EDRI

Household and government income and expenditure

[11] GDP at factor cost plus indirect tax, that is 355+30=385

[12] We deducted it from the total percentage value of government & household consumption and investment demand because it is deficit of 19.4% of total GDP.

Since our macro SAM separates households by level of income (poor and non-poor), it is possible to analyses how different household groups earn and spend their income. The total household income in our macro SAM comes from factor income, ROW and transfer from the government, which amounts to 375 billion birr from this income the household's received, 355 billion birr as factor income (174[13] as labor income, 110 as capital income, 40 as land income and 31 as livestock income which sum up to 355), 0.4 as transfer from the government and 19.6 as remittance from ROW. The total expenditure of household's accounts for 375, from this spending households spend 339 for consumption purpose (of which 153 (45%) for agricultural commodity consumption, 97 (28%) for industrial commodities consumption, and 88 (25%) for service commodities consumption), 6 for tax payment and 30 for private saving. On the side of government, the total government income accounts for 68, of which 34 from tax (direct and indirect tax) and 34 from ROW (grant and aid). The government also expended this income as government expenditure, the total government expenditure account for 68, of which 0.47 household transfer (pension, subsidies,…..), current expenditure (for administration 21 or 65% of total current expenditure, for education 9 or 28.1% of total current expenditure, for health 2 or 6.2% of total current expenditure.), the remaining 35 as government saving.

Table 4. 5 Summary of Household and government income and expenditure

Institution	Source	Amount	% share from total
Households income	ROW	19.6	4.97
	Transfer from Government	0.4	0.1
	Factor	355	94.94
Total		**375**	
Households expenditure	Tax	30	8.02
	Private Saving	6	1.6
	consumption	339	90.6
Total		**375**	
Government income	Tax	34	50
	ROW	34	50
Total		**68**	
Government expenditure	Transfers	0.47	0.6
	Current expenditure	32.53	47.9
	Government saving	35	51.5
Total		**68**	

[13] Out of such amount of labor income, the rural households have taken 156 and the remaining amount (18) of labor income taken by urban households.

Source: Author's Compilation from SAM for Ethiopia 2009/10 Developed by EDRI

4.2.2) Simulation Specification

In this section, we specify a series of different scenarios, each representing exogenous change in agricultural total factor productivity, which are used to analyses the effect of agricultural total factor productivity on the Ethiopian economy. In addition to the baseline scenario, we have three policy simulations that would allow us to measure the impact of policy shocks regarding the agricultural sector. In each of our simulations we run the model from 2009/10 up to 2016/17 as a base value simulation. Finally making policy simulation for 2017 until 2025, the year in which the country expects to achieve its national plan of middle income country. As described in the methodology, the sectorial growth accounting approach produces the estimates of TFP growth rates for the agriculture. Using the estimates of sectorial TFP, the panel data analysis model that considers exogenous variables identifies the powerful determinants of agricultural TFP growth in order to calibrate the induced agricultural TFP. Eventually, the study uses the estimated induced agricultural total factor productivity.

Base scenario

In the CGE modeling framework, it is essential to establish a baseline scenario that is counterfactual for comparing against the outcome of a policy shock. Hence, we begin with the baseline simulation. The model which we introduced, DCGE, is calibrated to reflect what would happen to the economy when there is no policy change and external shocks; and to generate the growth path over time or the economy can grow even without a policy shock., Analysis should be made with respect to the growth path in the absence of any shock (business as usual) or baseline scenario. The baseline scenario in this study assumes that business continues as usual with continuation of historical growth trends of 2009/2010 to 2016/2017 for additional eight years, from 2017 to 2025 with no specific changes made to policies.

Simulation 1 (low scenario)

Simulate agricultural TFP using our robust estimated result of agricultural TFP by using panel data estimation techniques, which is given in the above. Accordingly, an increase in the use of fertilizer by 1%, has an incremental impact on the agricultural TFP by 2.8%.

Simulation 2 (medium scenario)

One of the factors that can influence the agricultural TFP is the training and extension. Here again we use the above estimation result. An increase in the expenditure on training and extension by 1%, leads to induced agricultural TFP by 4.7%.

Simulation 3 (high scenario)

Finally we used the coefficient of research and development as the policy simulation, which is the crucial determinant of agricultural TFP**.** An increase of the expenditure on research and development especially on agriculture by 1%, has 5.8% increment in agricultural TFP**.**

4.2.3) Analysis of the Simulation Results

This section provides the results of the three scenarios discussed above and the implications of the results on macroeconomic, factor supply and income, household's income and expenditure, sectorial and welfare indicators of the economy. The analysis covers the period from 2017 to 2025.

4.2.3.1) Impact on Macroeconomic Variables

In this part we look at the impact of agricultural TFP on basic macroeconomic variables for each simulation in turn. Accordingly table below shows the summary results of the three simulation focusing on absorption, private consumption, fixed investment, government expenditure, government income, export, and import, and real GDP at factor cost and at market price, and CPI. According to table 4.6 and figure 4.1 all macroeconomic variables shows a sound and multiple effects compared to base case scenario except the consumer price index for which we can observe the negative value for all simulation scenarios. For instant, real GDP[14] at factor cost grew per year on average by 18.66%, 19.74%, and 20.28%, alternatively under figure 4.1 real GDP is 1.47, 2.55 and 3.09 percentage points higher than the base in respective simulations.

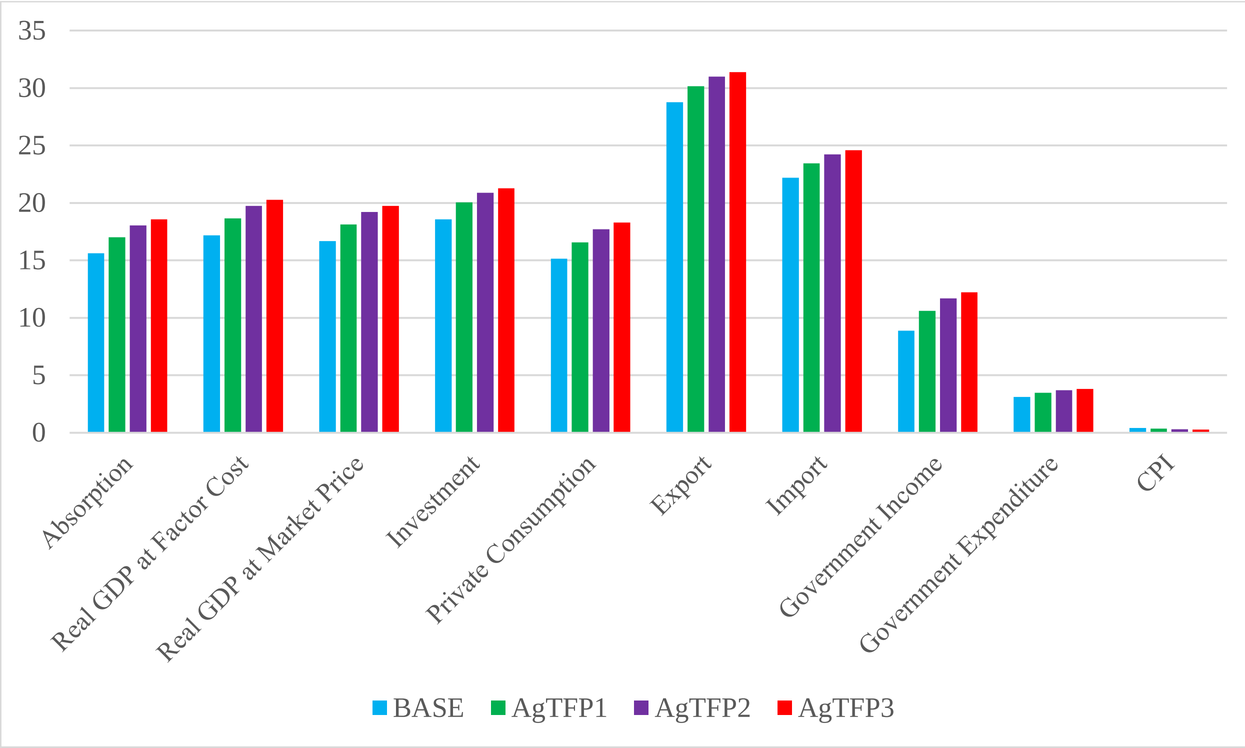
Table 4. 6 Simulation results of Macroeconomic Indicators (%change from base line simulation)

Variables	Initial	AgTFP1	AgTFP2	AgTFP3
Absorption	457.737	1.4	2.43	2.95
Real GDP at Factor Cost	354.952	1.47	2.55	3.09
Real GDP at Market Price	383.364	1.45	2.52	3.05
Fixed Investment	85.49	1.48	2.33	2.72
Private Consumption	338.611	1.42	2.57	3.15
Export	52.138	1.4	2.24	2.64

[14] GDP at factor cost is also known as total value added. It represents the earnings received by factors of production, such as employee compensation and gross operating services.

Import	126.51	1.27	2.04	2.41
Government Income	67.7794	1.72007	2.80937	3.32963
Government Expenditure	32.2926	0.34732	0.58644	0.69974
CPI	0.94793	-0.0737	-0.1245	-0.1516

Figure 4. 1 Simulation results of Macroeconomic Indicators (average % change per year)



Source: Own computation From Simulation Result

In this regard **GDP at factor cost** will upsurge in all simulation of agricultural TFP. This may be the fact that in this methodology (DCGE), the market structure is a perfect competitive market and the factors earn their value of marginal productivity. Then an increment in the agricultural TFP will boost the marginal productivity of factors; in turn, this also enhance the earnings of factors. As stated before GDP at factor cost a function of earnings received by factors of production, in such a way the increment in factor earning due to TFP enhancement has a positive multiplier effect on GDP at factor cost. Therefore the inducement of GDP at factor cost in all simulations may be because of the increment in factor income.

Table 4.6) indicates that **Consumer price index (CPI)** dwindled by 0.07, 0.12 and 0.15 percentage points compared to the base line scenario or alternatively under figure 4.1 Consumer price index

(CPI) waned by 0.34%, 0.29%, 0.26% per year on average compared to the base line scenario in all respective simulations. Inflation in Ethiopia is heavily associated with the dominant role of agriculture and food price in the economy, and also CPI inflation has two main component food and non-food price inflation (Durevall et al., 2010). According to central statistical report of 2018 the overall inflation rate is 15.20%, whereas food inflation rate is 19.90% and non-food inflation rate is 10.00%. Therefore improvement in the performance of agriculture sector through like enrichment of TFP has momentous impact on the general inflation by doing so lowering food price. This may occur because of the fact that, when we improved total factors productivity of agricultural sector has a multiplier impact on the total output production of agriculture sectors. Finally overwhelm of such output to the market will be plummeting the price of agricultural output price in the market.

Private consumption also amplified throughout all three that is increased by 1.42, 2.57, and 3.15 percentage points compared to the base line scenario, or 16.56, 17.71 and 18.29 percent per year on average all respective simulations. This is may be because of two main reasons: - the first one is mentioned earlier, according to UNDP 2014 report 80% of factors was employed in agriculture sector, therefore an increase in TFP in this sector will have a significant impact to increase almost all factors marginal productivity and tis again in turn to increase the income of households. When all's said and done households consumption would be increased (consumption linkages). The second reason is that agricultural sector output will uplift due to TFP which results in a decrease in the price (CPI) of agricultural outputs. Which is again leads to, on the side of firms they are enthusiastic to bought additional agricultural output as input of production for their business (forward production linkages); on the side of households, they also eager to bought additional product for their own consumption propose, finally the consolidation of these will leads to increase the private consumption.

As like other macro variables, **investment** shows a relatively good improvement in all simulations. it increased by 1.48, 2.33 and 2.72 percentage points compared to the base line scenario according to table 4.6 or , 20.04,20.89 and 21.28 percent per year on average according to table 4.1 on all respective simulations. Improvement of production in agricultural sector owing to TFP, which yield high quality and quantity of raw material with relatively lower price for other sector like agro industry and manufacture sectors, in turn this stimulates investment in other sector (forward production linkages). Alternatively the enlargement of agricultural sector production activity by TFP improvement, demands inputs such as tractors and harvesting machineries for further production from sectors other than agricultural sectors (backward production linkages). To address such demand of inputs by agricultural sector, the other sectors have to increase their investment to produce the commanded amount of inputs. In addition to this due to increment in private consumption the firms also increase their investment to meet and benefit the increment in consumption demand.

In all scenarios both aggregate **import and export** increased as the result of improvement in agricultural TFP. Since the increase in real export outweighs the increase in the real import which mend the trade balance. Export grew by 1.48, 2.24 and 2.64 percentage points compared to the base line scenario all respective simulations. Import grew by 1.27, 2.04 and 2.41 percentage points compared to the base line scenario all respective simulations. The intuition is that imported demand[15] is a function of the relative price of domestic and foreign commodities price, in such a way the price (CPI) of domestically produced commodities were reduced. Therefore consumer shift its demand from imported commodities to domestically produced commodities, at the end of the day this is leads reduced the increment of import relative to increment of export. In addition, agricultural production activity improvement due to encroachment in TFP leads to increased agricultural output growth in both quality and quantities compare to imported commodities. Finally there will be import substitution of agricultural commodities by domestically produced agricultural commodities, which is leads to again tumbling the amount of imports increment relative to export increment. Yet again export demand[16] is a function of the relative price of domestic and foreign commodities price, in such a way the price (CPI) of domestically produced commodities were reduced will leads to eager exporter to export the commodity rather than sold to domestic market. This also increasing the average export growth rate. As well as according to UNDP report, 70% of export originated from agricultural sector. Therefore, an improvement in the production of output in this sector due to the above reason directly increases the aggregate real export of the country. Since in the preceding case the increase in real export outweighs the increase in the real import tends to **mend the trade balance**.

[15] Which is governed by a Constant Elasticity of Substitution (CES) function
[16] Which is governed by Constant Elasticity of Transformation (CET) function

Government income increased by 10.6, 11.6 and 12.2 percent per year on average in simulations 1 up to 3, respectively, according to figure 4.1 or alternatively increased by 1.72, 2.8 and 3.32 by percentage points compared to the base line scenario in three respective simulation scenarios. Government income is a function of both direct and indirect tax, transfer and trade surplus so that as stated above boost in private consumption will leads to the government to charges additional indirect tax like VAT (value add tax) and TOT (turn over tax) on thus private consumption, moreover sectorial investment was stimulates this also increase government income on the side of charging indirect tax on such sectors. Because of increasing the income (return) of households the government also charges additional direct tax this again increase the income of the government. Finally as we have seen before the average growth rate per year of export is higher than import this leads to improving trade balance and this also leads to the government income also improved.

In the same fashion **government expenditure** also increased in simulations one to three, respectively, by 3.4, 3.6, and 3.8 percent per year on average according to figure 4.1 or alternatively increased by 0.34, 0.58, and 0.69 by percentage points compared to the base line scenario in respective simulation scenarios. This will be the case of, government expenditure is a function non-governmental institution transfers and commodity consumption demand, then an increasing in the government income leads to increasing the transfer of non-governmental institution, and this would be a case for increasing the government expenditure. Another case may be, as stated before investment and sectorial production (due to inter-sectorial linkage to agriculture sector) will better stimulated under all simulation than before policy simulation scenario (base) this required adequate public infrastructure. Therefore the government would have enthusiastic to be increased expenditure on infrastructural and other social need related to investment to incessant the growth path of such sectors and investment. Finally the due to increasing government income may leads to increasing the expenditure of the government. **Absorption,** which is the total demand for all final marketed goods and services by all economic agents resident in an economy, regardless of the origin of the goods and services themselves, indicates that there is an increase by 1.4, 2.43 and 2.95 percentage points in scenario 1, scenario 2 and scenario 3 as compared to the base line scenario, respectively. The reason that increasing absorption is due to increase in investment, private consumption and government expenditure. Final **GDP at market price** increased in all simulations by 18.13, 19.2 and 19.73 percent per year on average in the respective scenarios according to figure 4.1 or alternatively increased by 1.45, 2.52 and 3.05 by percentage points compared to the base line scenario in respective simulation scenarios. This is happed because of the GDP at market price is a function of private consumption, government expenditure, investment and improvement of net export. Therefore, aggregate impact of the results of increasing private consumption, government expenditure, investment and improvement of net export will finally increase GDP at market price.

4.2.3.2) Impact on Sectorial Performance

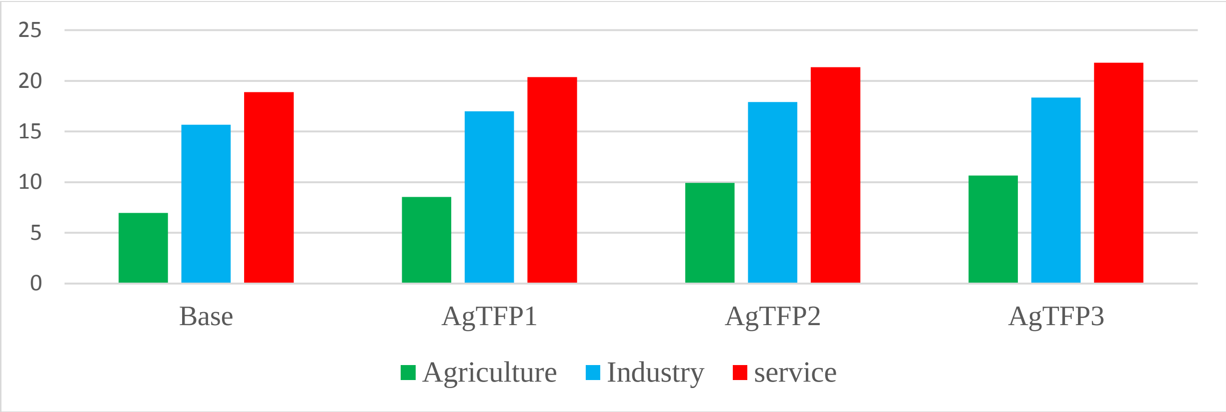
Under this topic we present the effects of the simulations on the agricultural, the industry and the service sectors growth. For the purpose of reporting, we have aggregated activities into three: agricultural, industrial and service sectors. Figure 4.2 represent the average growth rate per year of sectors[17], which postulates that the average growth rate of the sectors increased throughout all simulations. Table 4.7 indicates that agricultural sector grows by 1.58%, 2.969% and 3.679% in all respective simulations, compared to the base line scenario. The industrial sector grows by 1.33%, 2.25% and 2.69%, respectively, in all respective simulations as compared to the base scenario. The service sector also grows by 1.46%, 2.44% and 2.91% under in all respective simulations, as compared to the base line scenario.

Table 4. 7 Sectorial Impact of agricultural TFP (percentage change from base line simulation)

Sectors	AgTFP1	AgTFP2	AgTFP3
Agriculture	1.587	2.969	3.679
Industry	1.332	2.2528	2.6948
Service	1.469	2.444	2.913

[17] Average percentage change in sectorial output is calculated by aggregating output of activities into total outputs of agricultural, industrial and service sector for each year. Then the mean growth rates is calculated from the annual growth rates of each sector.

Figure 4. 2 Sectorial Impact of agricultural TFP (average % change per year)



Source: Own computation From Simulation Result

In all the simulations sectorial output has shown positive growth in the agricultural, industrial and service sectors, notwithstanding the growth of agricultural sector outweigh the others sectors this because the policy simulations (TFP) were solely on agricultural sectors and keep other sectors as business as usual. Therefore any shock on the values of TFP first and for most affect the performance of agricultural sector directly, which will be transmitted to other sectors (inter-sectorial linkage) either directly or indirectly through production and consumption linkages. This could be explained by, in simulation-1 agricultural TFP increases by 2.8 because of increase in the usage of fertilizer. Fertilizer significantly enhances natural soil nutrients and as a result per hectare production is increased in agricultural sector and also to feed such demand of fertilizer in agricultural sector, the factories in the industrial sector must be increased their production(import linkages). In simulation-2 also agricultural TFP increases by 4.7 because of training and extension. A population that is well educated and trained helps a society to increase its ability to acquire as well as use relevant knowledge. Training and educating the agricultural sector laborers (farmers) about how to use and adopt new innovated technology will encourage mechanized farming, and modern farm managements, and how to keep their health and etc., this in turn contributes to increased agricultural outputs and activities expansion compared to the base scenario. In the last simulation agricultural TFP increases by 5.7 because of research and development. Agricultural research and development (R&D), in general, contributes to agricultural growth and total factor productivity (TFP) by increasing crop and livestock yields through development of new technologies (that is, new varieties and techniques) and increased technological diffusion and adoption. Agricultural research is required not only to increase agricultural productivity, but also to keep productivity from falling. As well as the enhancement and improvement of production in agricultural sector has a positive and significant impact on industry sector through forward production linkages that is agriculture stimulate the industry sector growth by provided more quantified and qualified raw material to industry sector(especially agro-processing factories); through backward production linkage that is agriculture sector stimulate the industry sector growth by acquiring a raw material(like fertilizer, harvesting machines, pesticides and etc.) from industrial sector for production and harvesting. In line with this education and training of the farmers requires human capital to educate and giving training for such farmers; therefore this leads to increase in the growth of service sectors. Accordingly to state early investment and production is stimulates in agricultural and industry sector this will leads to increase the performance of service sector growth rate. Through, when we increase investment in industry and modern agriculture will result, increasing the demand skilled manpower, in a line with this the service sector will increasing is production(education) to meet such demand. Furthermore both the growth of export and import trade were increasing significantly, this also improving the country trade performance, which is implicitly means that improved the growth of service sectors. Conducting such research and development; to tech and trains the farmers requires educated human capital, and so that to disseminate such research & development and training & extension we should increase the growth of service sector. In addition according to Keynesian analysis demand derives supply. Therefore, the underlying reason for increase in the growth of agriculture and service sectors in all respective simulations could be emanated from the increment of aggregate demand that encourages producer to produce more goods and services in both sectors. Such increment in aggregate demand is mainly due to increases in investment, private consumption (along with decrease in the price of product due to declines in consumer price index which in turn increases the purchasing power of households), export demand and government expenditure.

4.2.3.3) Impact on Factor Income and Factor Supply

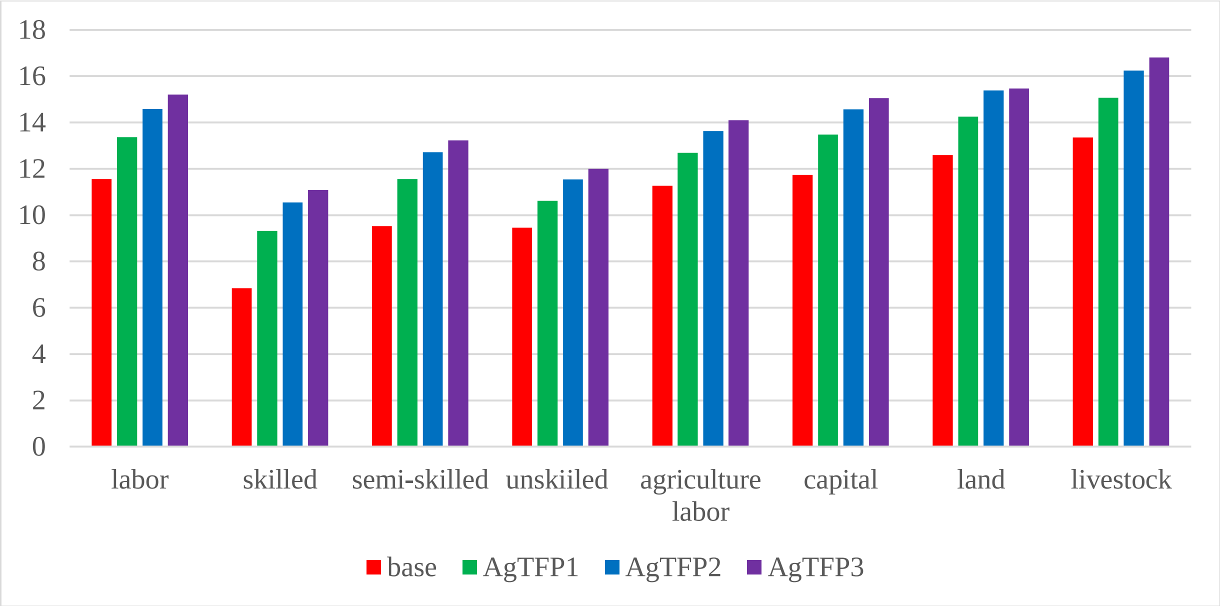
A) Factor Income

In relation to returns to factors of production, the results from the CGE model are provided in the Table 4.8 and Figure 4.3. Aggregate factor income has improved in all simulations. However, the higher growth rate in labor income is obtained in all simulation compared to the growth of other factors. Labor returns rises by 1.81, 3.03, and 3.64 of percentage points compared to the base line scenario or 13.3, 14.59, 15.2 percent per year on average respectively on the respective simulations.

Table 4. 8 Summary of Factor income (percentage change from base line simulation)

Factors	Initial	AgTFP1	AgTFP2	AgTFP3
Labor	**174.02**	**1.81**	**3.037**	**3.647**
Skilled	30.47671	2.466	3.699	4.235
Semi-Skilled	84.90408	2.032	3.194	3.706
Unskilled	58.63321	1.152	2.075	2.540
Capital	**110.324**	**1.752**	**2.839**	**3.320**
Land	**39.76**	**1.662**	**2.8**	**2.882**
Livestock	**30.85**	**1.715**	**2.88**	**3.46**

Figure 4. 3 Summary of Factor income (average % change per year)



Source: Own computation From Simulation Result

The reason behind returns to labor to have shown higher improvements compared to the other factors in all the three simulations could be that according to Ethiopia 2009/2010 SAM characterization out of all factors of production which is used as input of production 49.1% was account as labor, therefore an improvement in overall economy performance will leads to a higher increasing in the return of labor compare to the remaining factors of production. Also labor productivity increased because of improvement in TFP this leads to increase return of labor because factor earn its values of marginal productivity . Alternatively in the closure part of factor market of this study is not fully employed and mobile across sectors, therefore over all increasing in investment and production activity in all sectors will make a chance for laborer to increase return. From the average growth of labor income, skilled and semi-skilled labor take a lion share respectively compare to unskilled labor. This may be case of, when we improve the agricultural TFP by using fertilizer usage, research & development and training & extension, in turn, to conduct such activity (like conducting agricultural research, teaching and training the farmer) and to use such results (like pesticide, fertilizer, education, vaccination, better farm management, mechanized farming), must engaged the skilled labor more and semi-skilled less compare to skilled laborer. Therefore the income of skilled and semi- laborer have high returns relative to un-skilled laborer. Capital income also shown higher improvements compared in all simulation to the base line, this is because of, according to Ethiopia 2009/2010 SAM characterization out of all factors of production which is used as input of production 31.1% was account as capital, therefore an improvement in overall economy performance will leads to increasing in the return of capital. Also capital productivity may be increased because of improvement in TFP this leads to increase return of capital because factor earn its values of marginal productivity. Finally the return of land and livestock also increases in all simulation; this is because due to the improvement of our policy simulation (TFP) of agricultural sector will leads to the increasing the productivity of land and livestock and increase agricultural sector production more than the other sector production growth . Almost all land and livestock were employed in agricultural sector therefore the output production improvement in agricultural sector leads to increasing the returns of land and livestock additional when land and livestock productivity improved, their returns also increase because factors earn their value of marginal productivity. In general, the increase in factors income is because of increase in production of activities in all the sectors (industry, service and agriculture), this also create additional income to the factor other compared to the base line scenario. Another factor for the increase in the total factor return is decline in CPI, and this also the surge the remaining income of factor after paying for transaction. In addition, as stated earlier, improved factors marginal productivity attributable to improvement in TFP also increase the return of factors because under DCGE model factors receive their marginal productivity and also their productivity increase because of TFP results in the increase in their returns. Overall, the huge investments and the resulting faster GDP growth result in substantial increases in returns of inputs.

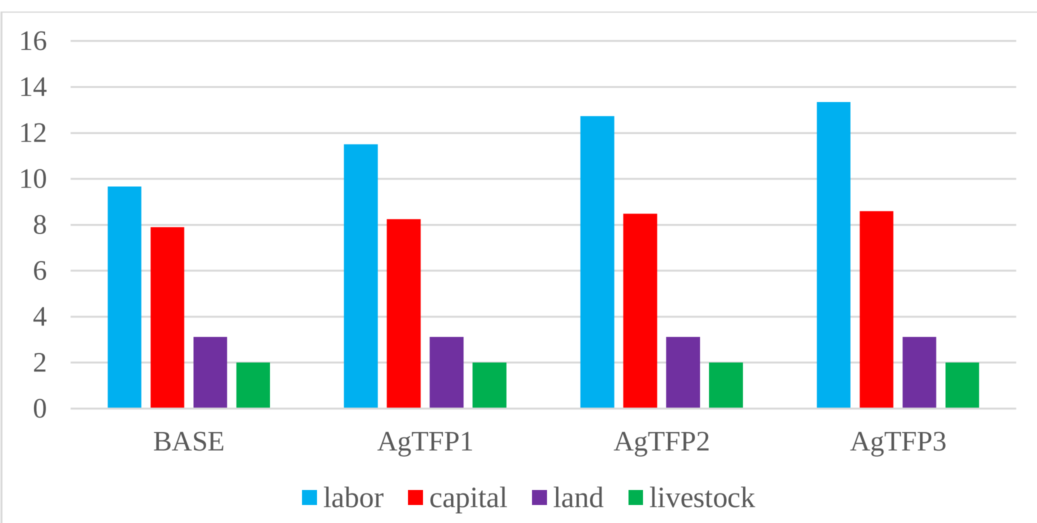
B) **Factor Supply**

In this part we look at the impact of agriculture TFP on the factor supply. Accordingly table 4.9 below summarizes the effects on factor supply in all simulations. According to table 4.9 there is improvement in labor and capital supply due to the impact of agriculture TFP in all simulations. The supply of labor rises by 1.8, 3.06, and 3.6 percentage points compared to the base line and the supply of Capital rises by 0.35, 0.58, and 0.69 percentage points compared to the base line in all respective simulations, however there is no change is the supply of land and livestock.

Table 4. 9 Summary of Factor Supply (percentage change from base line simulation)

Factors	Initial	AgTFP1	AgTFP2	AgTFP3
Labor	174.02	1.835	3.067	3.672
Capital	441.3	0.35	0.58	0.69
Land	1383.31	0	0	0
Livestock	30.85	0	0	0

Figure 4. 4 Summary of Factor Supply (average % change per year)



Source: Own computation From Simulation Result

Notwithstanding, the labor supply growth rate also higher than capital supply growth rate. As stated early the activities that enhanced the growth of agricultural TFP (technology) like research & development and training & extension demanded relativity a given amount of capital and labor relative to other inputs. Therefore to meet the demand of capital and labor, the households increase the supply of both factors. Finally as we have seen no more significant change in factor supply this is the fact that when we induced the TFP which is leads to increasing the efficiency of the existing factors of production rather factors of production quantity, this also leads to increasing production without farther increment the quantity of factors of production rather we have to increasing their efficiency and quality. However to induced TFP we must have to require some inputs accumulation in a small quantity, since this leads to a little bit increment of most required inputs to TFP (technology) improvement, that is capital and labor, the supply growth of the inputs of production(land and livestock) remains stagnant.

4.2.3.4) Impact on Household's Income and Consumption Expenditure

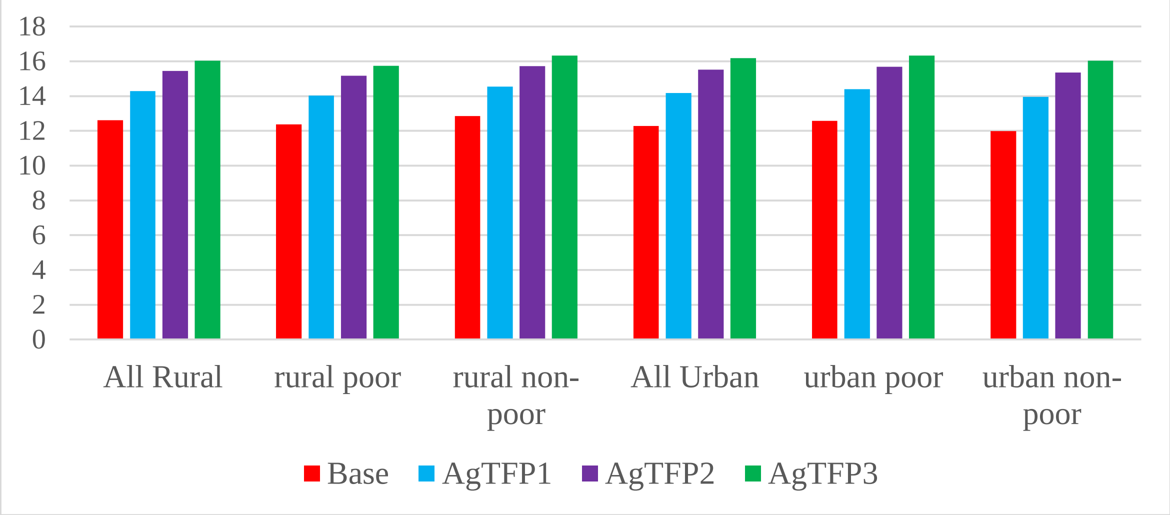
A) Impact on Household Income

The primary sources of income for households are factor payments generated during production. They also receive transfers from other institutions like government, other domestic institutions and the rest of the world. We can analyses the impact of agricultural TFP on household's income using the results in Table 4.10 or Figure 4.4. In relations to income of households, the CGE result shows similar change like output and returns to factors of production. As can be seen from the figure 4.4 both rural and urban households would experience an increase in their real incomes compared to the base case in all simulations i.e. as show in figure 4.4 rural households income grew by 14.2, 15.4, 16 percent per year on average on the respective simulations and the urban households income also grew by 14.1, 15.5, 16.1 percent per year on average on the respective simulations. This is due to, first as stated early factors income have increased significantly due to advancement in agricultural TFP, this in turn increased the income of both rural and urban households in the portion of factor income, Which is contributed around 94.9% of households total income according to 2009/2010 Ethiopia national SAM, therefore households income is increased. Second, due to increase in government income, which is a source of household income through transfers (pension), infrastructural development, public investment will leads to the household's income to increase. Finally, there is increase in overall production is due to agricultural TFP enhancement leading to increase in household income.

Table 4. 10 Summary of Household Income (% change from base line simulation)

Households	Initial	AgTFP1	AgTFP2	AgTFP3
Rural	**335.01**	**1.675**	**2.838**	**3.419**
Rural Poor	73.93	1.65	2.794	3.366
Rural Non-Poor	261.08	1.7	2.882	3.472
Urban	**39.37**	**1.895**	**3.235**	**3.9**
Urban Poor	3.83	1.82	3.11	3.75
Urban Non-Poor	35.54	1.97	3.36	4.05

Figure 4. 5 Summary of Household Income (average % change per year)



Source: Own computation From Simulation Result

In all simulations the income of urban household increases faster than the income of rural households, i.e. as shown table 4.10 urban households income grow by 1.89, 3.23, and 3.9 of percentage points compared to the base line scenario, rural household income grow by 1.67, 2.83, and 3.4 of percentage points compared to the base line scenario on average per year in respective simulations. This is mainly due to, first, due to improvement in agricultural TFP there is increment in output growth especially in agricultural sector, this in turn benefited the rural dweller by increasing their income more than the urban one. However, in long run the price (CPI) of output was decline in such a way it benefits the urban dweller by increasing their income more than the rural dweller. Second, average growth of return of labor also higher compare to other factor return, of which labor returns the skilled and semi-skilled has a higher share. This means that most of skilled and semi-skilled laborer were dwelling at urban area, finally the income of urban dweller turn to boom out relative to the rural dweller. Third, as stated early, Increasing government transfer and increasing government expenditure to financed infrastructure, health, education and other social developments, such action may be benefited the urban dweller to increasing their income compare to the rural one. In general, in all simulation and household groups the non-poor are more benefited as compared to the poor, which may be the case that when investment aggravated, production activity also become rampant, government also inflamed expenditure on social development and infrastructure, will leads to primarily non-poor households in both urban and rural become more benefited, whereas the poor households is not such as a significant changes in income relative to the non-poor households. This is because poor households, most of the time, get additional income by selling their labor and capital to other institutions and non-poor households. On the other hand the non-poor households get additional income not only by selling their labor and capital but also participated in profitable investment and obtain more additional income (profit) from their investment relative to poor households.

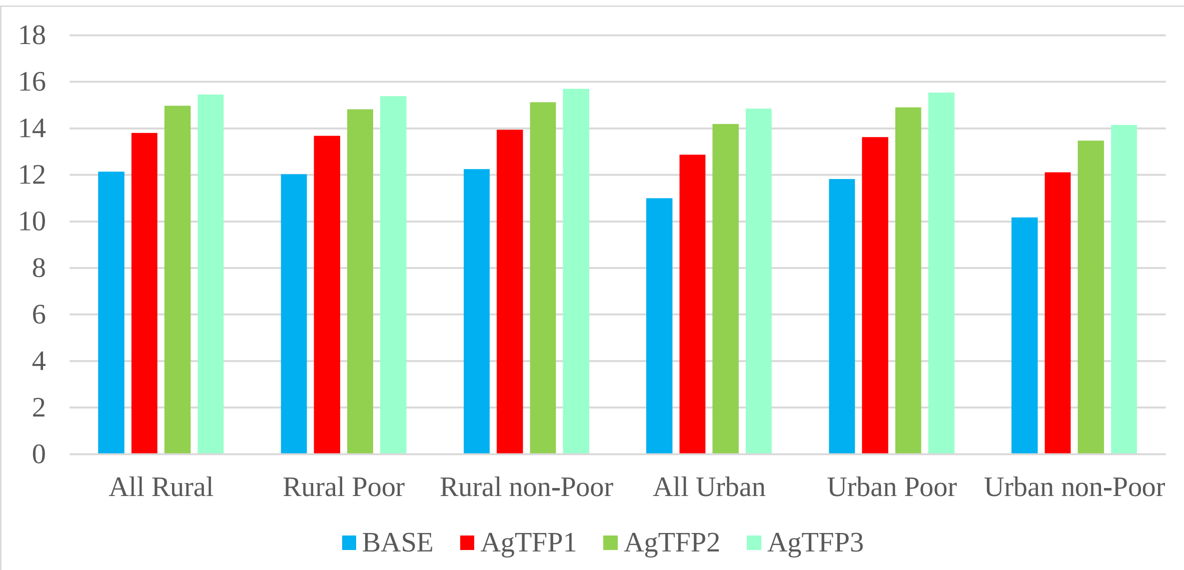
B) Impact on Household Consumption Expenditure

Before we explain the effect on household consumption expenditure, there is a need to classify household into rural poor, rural non-poor, and urban poor, urban non-poor. From table 4.6, rural households consumption expenditure grow by 13.8, 14.9, and 15.4 percent on average per year relative to the base line simulation and also urban households consumption expenditure grow by 12.8, 14.1, and 14.8 percent on average per year relative to the base line simulation in respective simulations.

Table 4. 11 Summary of household Consumption expenditure (% change from base line scenario)

Households	Initial	AgTFP1	AgTFP2	AgTFP3
Rural	**308.149**	**1.666**	**2.826**	**3.305**
Poor	70.181	1.643	2.786	3.358
Non-poor	237.969	1.689	2.866	3.449
Urban	**30.461**	**1.872**	**3.198**	**3.852**
Poor	3.426	1.807	3.089	3.721
Non-poor	27.036	1.938	3.307	3.982

Figure 4. 6 Summary of household Consumption expenditure (average % change per year)



Source: Own computation From Simulation Result

Agricultural TFP results in increase in expenditure for both poor and non-poor rural household in all simulation scenarios. Households spend their net income (income less saving, taxes and transfers) on consumption. According to Ethiopia's national SAM of 2009/2010 a representative household spend 90.6% of its total income for consumption purpose. As mentioned early households' income boom out because of increase in factors income, government transfer, investment, production and so on. Therefore, there may be a way of increasing consumption expenditure of households. Due to improvement in production activity sectors produce large stock of outputs, which results in the supply of additional outputs to the market. Finally, due to increasing the supply of output to the market, there is a reduction in price this again household's eager to increasing its consumption compare to before, in order to whether benefited from price reduction or deserved additional supply of outputs. At the end of the day improvement in agricultural TFP will increase the real income of household and enable them to spend more to meet their needs. As per the results in table 4.11, the growth rate of consumption expenditure of urban households compare to base line simulation are merely larger than the rural households because urban household's income growth is higher than the rural households. This contributed to increase in the consumption expenditure of urban households than their rural counterpart. When we compare poor and non-poor households of both dwellers, it is found that the non-poor households' consumption expenditure merely better than the poor households. This is because non-poor households of both dwellers make a significant increment in income for all simulations compared to the poor households. Finally this also significantly increases consumption expenditure of non-poor households other than the poor one.

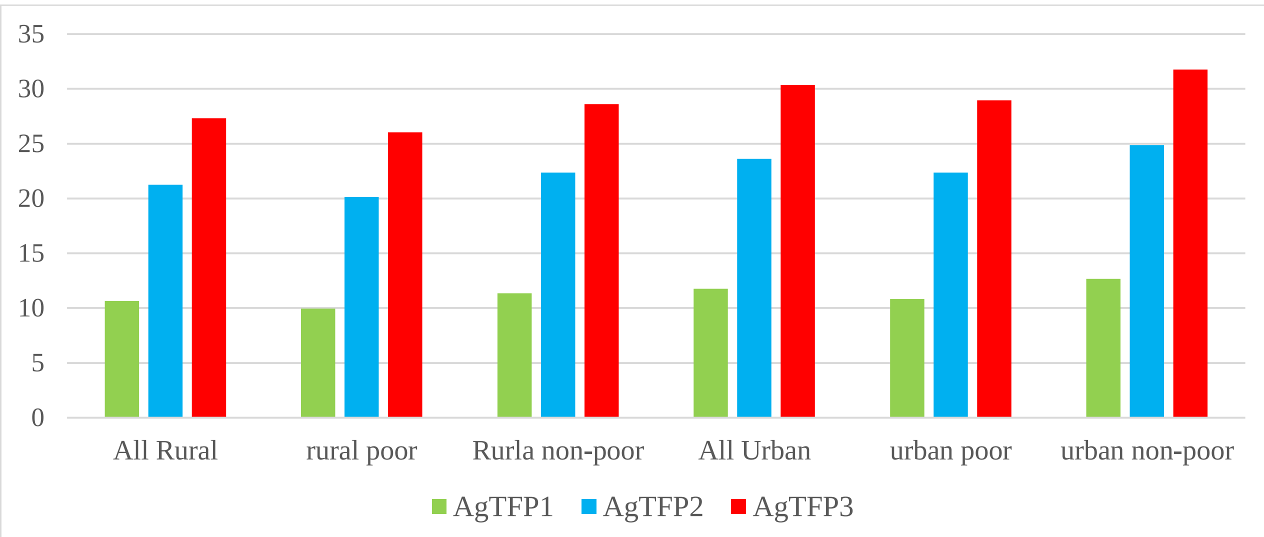
4.2.3.5) Impact on welfare of households

Welfare refers to social wellbeing of all the people in terms of utility. The CGE model uses a technique of the Equivalent Variation (EV) in order to measure welfare change in terms of change in utility that arises from policy shocks. The EV in this regard considers the change in price and income between the base year price and the current year price. As it is a measure of wellbeing of the society, a positive EV indicates the existence of welfare gain due to policy change and negative EV implies loss of welfare (Zerayehu, 2013). Alternatively, the welfare of society can be indicated by using equivalent variation which is the most important indicators of the welfare effects of policy reform. Since policy shocks are usually followed by major price adjustments, the EV measures the level of income (in money terms) that the consumer needs to pay before the shock to leave him as well off at the equivalent level of utility changes after the price changes. From any policy change, consumer can be harmed or benefited prior to the policy change by paying or receiving the price equivalent in income, negative or positive EV changes represent welfare (utility) loss or gain as a result of the policy shock.

Table 4. 12 Summary of Welfare Impact (% Change from Base Case Simulation)

Households	Initial	AgTFP1	AgTFP2	AgTFP3
Rural	**338.61**	**10.651**	**21.248**	**27.321**
Rural Poor	73.61	9.952	20.146	26.036
Rural Non-Poor	265	11.35	22.35	28.606
Urban	**30.47**	**11.75**	**23.61**	**30.365**
Urban Poor	3.43	10.83	22.36	28.96
Urban Non-Poor	27.04	12.67	24.86	31.77

Figure 4. 7 Summary of Welfare Impact (average % change per year)



Source: Own computation From Simulation Result

According to Figure 4.6, in all simulations, EV reveal positive change for all household category compared to baseline scenario. It will because of, there is enhancement in production activity in all sectors will leads to increases the output of the such sectors specially in agricultural sectors, in a line with this the output price (CPI) also decline. This leads to household's consumption increase compared to the base line scenario, and at the end of the day household's welfares improves. In addition, welfare of society can be indicated by using income of households, which means when households received additional income emanated from expansion of investment, increment in GDP, augmentation in factors income and government income, finally which make households eager to consume more than before, again this contributes to welfare improvement. However, the growth rate of the welfare gain of rural households compare to base line simulation were higher than the urban counterparts, that is urban household's welfare improved by 11.75, 23.61, 30.36 percentage points compared to the base line in all respective simulations and rural household's welfare improved by 10.65. 21.2, 27.3 percentage points compared to the base line in all respective simulations, this is because on both increment in income and consumption expenditure the urban dweller is better and higher than the rural dwellers. And also the urban poor has a higher welfare improvement than the urban non-poor, this happens because most poor households' live subsistent way of life and they are also hurt by the consecutive agricultural outputs price change. Therefore, the advancement and increment in both agricultural production activity and outputs improves the welfare of the urban poor than the urban non-poor by lowering the CPI, and increasing the stock of agricultural outputs.

Chapter Five: Conclusions and Policy Implications

5.1 Conclusion

Ethiopia has gone through three ideologically distinct political regimes: the monarchic regime during 1950-1974, the central planning regime (*Derge* regime) during 1974-1991, and the regime that has been in power since the collapse of *Derge* regime in May 1991, the EPRDF. Each political regime has its Owen impact on agricultural sector directly and indirectly through their economic policies in terms of both access to factors of production and marketing of inputs and outputs. The Ethiopian economy in the last decades has been growing in different fashions depending on the economic policies undertaken by the ruling governments at their times. The economic performance is characterized by positive and negative growth rates, ranging from 13 percent and negative 11 percent in 1981-2010. Although agriculture is one of Ethiopia's most promising resource for the economy (i.e. it contributes about 42% to GDP, with 80% to employment and 70% to export earnings), the productivity of the sector has been slowed down by a periodic drought (because mostly the agricultural production is rain-fed), poor infrastructure, over grazing, deforestation, poor farm technology, poor farmer training and extension service, poor health of the farmers, less access to international market of the product of the farmer directly, fragile agricultural research and development. Ethiopia with about 51.5 million hectare of arable land, however, just over 20% is currently cultivated mainly by small holders. The land tilled by the Ethiopian small-scale farmers accounts for 95% of the total area under agricultural use, over 50% of farmers operates on at most one hectare and these farmers produce more than 90% of the total agricultural output. In addition about 44 percent of the total population (45% in rural and 37% in urban areas) were found to be below poverty line and 40% of the households are still food deficient using the threshold of 2550 kilocalories per adult equivalent per day. To address such problems and increasing the productivity of such inadequate plot of land per households, this paper focused on agricultural technological (TFP) improvement on the economy by taking into account the other predominant factors that are induced/adverse effect on agricultural productivity. Because TFP is one of the principal, sources of perpetual growth as it has a nature of an increasing return to scale. In this study, we attempted to examine economy wide impact of technological shock on agricultural sector using a recursive dynamic CGE model. The study used an updated version of the 2005/06 EDRI Social Accounting Matrix for DCGE model. Whereas for the econometric estimation we utilized the agricultural sample surveys data of CSA and data from Ethiopia ministry of agriculture, WB, IMF, and so on. The study identifies the key determinant of TFP using panel data analysis to estimate the value of agricultural TFP of these determinants. Out of the determinants, fertilizer, training & extension and research & development are statistically significant and positively influence the agricultural TFP. This allows using these values of TFP for policy simulation purpose. Using these values of agricultural TFP, the dynamic CGE model examines the impacts of such induced agricultural TFP growths on economy wide growth. We used three simulations to evaluate economy wide impact of agricultural TFP. Such as, simularion-1 increasing agricultural TFP by 2.8 due to amassed usage of fertilizer, simulation-2 increase agricultural TFP by 4.7 owing to increasing the expenditure on farmer training and education, simulation-3 increase agricultural TFP by 5.7 by increasing the expenditure on agricultural research and development.

The paper assessed the impact of increasing agricultural TFP on aggregate macroeconomic and sectorial variables, welfare of the households, factor income, household income, factor supply, household's consumption expenditure. The simulation exercises result significant increase in most macroeconomic variables in all simulations except CPI, such as increased absorption by 2.95, GDP at factor cost & at market price by 3.09 & 3.05, investment by 2.72, private consumption by 3.15, export by 2.64, import by 2.41, government income & expenditure by 3.3 & 0.6, in the last simulation (increasing TFP by 5.7) compared to the base simulation. However, CPI fell by 0.15 percentage point compare to base simulations. When we look the results of policy simulation on sectorial performance, improvement of the production activities of all sectors performance, especially, agricultural sector is seen. On the other hand, factor supply has not shown significant change, i.e., the supply of labor and capital has a little changes in all policy simulation compared to its base line simulation. Whereas Factor and households income shows a large increment in all simulation compared to base simulation, as result of overall increase in economic performance which is perceived by increase in GDP at factor cost & market price, investment, government income & expenditure. There is also increase in both rural and urban poor and non-poor dwellers household consumption expenditures in all simulations. Finally, the welfare of the overall households were improved in a momentous manner, which is witnessed by increase in households income, households consumption, investment, GDP at factor price & market price, government expenditure & income and finally dwindling of CPI.

5.2 Policy Implications

Our simulations finding evidenced that the improvement of agricultural TFP has a positive and significant multi-sectorial and economy wide impacts. Some of the outcome of simulations such as increasing the government income and expenditure, increasing GDP at market price & factor cost, reducing CPI, improving welfare of the households, advanced the performance of all sectors of the economy. Considering countries' experience, econometric and simulation results, this study recommends that the government and the concerned policy maker could undertake the following policy actions for securing sustainable growth.

First, there must be a series economic policy revisions focusing on enhancing total factor productivity. This is witnessed by the positive and significant economy wide impact of the policy simulation scenarios of increasing agricultural TFP against the base-run scenario. For instance, in many cases, consumption expenditure of the society has a higher share of their income. In the case of our country food and food related commodities price has been over values through time, this again leads to, deteriorate the purchasing power of the people and welfare of the society, higher cost of living, additionally its leads to a macroeconomic problems (like inflation). This will arise by the fact that, insufficient supply stock of food and food related commodities to the market because of lower productivity in agricultural sectors align with a higher population growth rate. Notwithstanding, in our simulations improvement of agricultural TFP has outshine impact on the sectorial activity as long as sectorial output growth, at the end of the day it is also hallmark effect on CPI by tumbling it and also improving the welfare of the households as a result of reduction of CPI, increasing their income and expenditure.

Secondly, among the determinants of sectorial TFP growth, fertilizer usage, research & development, and farmer training & extension are the most prominent factors that induced agricultural TFP, therefore the government should give a special attention for enhancing agricultural TFP in order to achieve sustainable economic growth and national food self-sufficiency.

Thirdly, Agriculture has continued to retain its importance in Ethiopia's economic growth contributing about 40% of GDP, with 80% of employment and 70% of export earnings and 70% of raw material requirements for large and medium agro-processing industries. Due to the plan of the government (like GTP) the share of agriculture to GDP reduced throughout a year, it may be because of government give less emphasis to agriculture , on the contrast giving more prominence to other than agricultural sector in order to transforming the structure of the economy to industrial sector based. This may be leads to in log run foreign exchange constraint (because of agricultural sector account for 70% of export earnings), structural change miss-leading (transformed the structure of the economy to service sector biased rather than industrial sector base), depressing the quality and quantity of agricultural raw material to industrial sectors. While in our simulation results of improving agricultural sector activity through like improving the TFP leads to increasing export higher than import this again in trade leads to the long run boom out our foreign saving, amend trade balance, plummeting our foreign currency constraint. And also the simulation results ameliorate sectorial output growth rate, this witness for structural transformation and inter-sectorial linkages. Finally, this paper recommends that the government should give attention to agricultural sector development as much as its gives to the industrial sector, rather than dwindling the performance and GDP share of agriculture in the name of structural transformation.

Finally, mending the productivity of agricultural sector through land expansion and capital accumulation may not be sufficiently and successfully attained a long run growth, this is because of limited its quantity that is we could not exploited it as what we wants. Moreover, it is subject to diminishing return. Even though to improve, the productivity of agricultural sector through enhancing TFP (technology) were better and prime apparatus, for the reason of, TFP were not subjective to diminishing returns rather than increasing return with the existing inputs of production(or without required additional inputs of production). In addition, intensify agriculture through TFP resulting in a decreased requirement for additional agricultural land that would primarily be taken from forests. Therefore, this paper recommended that increasing the productivity of agricultural sector via enhancement in TFP is a prime and leading mechanism rather than capital accumulation and land expansion.

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APPENDIXIES

Appendix A: Basic Econometrics Models Diagnostics Tests

Appendix A.1: Hausman Test

```
hausman fixed random

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     fixed        random       Difference          S.E.
-------------+----------------------------------------------------------------
         frt |    2.800851     .0508761        2.749975        .2868171
         psd |   -2.881551     .0093682       -2.890919        .6952725
         irg |   -.0600163    -.0034932       -.0565231        .0057533
          rd |    5.796523     5.202251        .5942719               .
          te |    4.709384     2.122771        2.586614               .
          to |   -.0380668    -.0203221       -.0177446               .
         inf |    .0393121     .0335517        .0057604               .
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg
    Test:  Ho:  difference in coefficients not systematic
                  chi2(7) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =       91.73
                Prob>chi2 =      0.0000
                (V_b-V_B is not positive definite)
```

Appendix A.2:The Fixed Effect Model

```
Fixed-effects (within) regression               Number of obs      =       126
Group variable: commodityrun                    Number of groups   =        18
R-sq:  within  = 0.5293                         Obs per group: min =         7
       between = 0.8184                                        avg =       7.0
       overall = 0.0749                                        max =         7
                                                F(7,101)           =     16.23
corr(u_i, Xb)  = -0.9998                        Prob > F           =    0.0000
------------------------------------------------------------------------------
       agtfp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         frt |   2.800851   .2876704     9.74   0.000      2.23019    3.371511
```

```
         psd |  -.2881552   .0705953    -4.08   0.000    -.4281972   -.1481131
         irg |  -.0600163   .0061211    -9.80   0.000    -.0721588   -.0478737
          rd |   5.796522   1.832752     3.16   0.002     2.160836    9.432209
          te |   4.709384   2.243506     2.10   0.038     .2588721    9.159896
          to |  -.0380667   .0157293    -2.42   0.017    -.0692694   -.0068641
         inf |   .0393121   .0282578     1.39   0.167    -.0167437     .095368
       _cons |  -4209.045   1818.514    -2.31   0.023    -7816.488   -601.6025
-------------+----------------------------------------------------------------
     sigma_u |  1823.8908
     sigma_e |  34.073497
         rho |  .99965111   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(17, 101) =     5.57             Prob > F = 0.0000
```

Appendix A.3:Heteroskedasticity Test

```
Modified Wald test for group wise heteroskedasticity in fixed effect regression model
H0: sigma(i)^2 = sigma^2 for all i
chi2 (18)  =   11902.82
Prob>chi2 =      0.0000
. xtreg agtfp frt psd irg rd te to  inf , fe robust
Fixed-effects (within) regression               Number of obs      =       126
Group variable: commodityrun                    Number of groups   =        18
R-sq:  within  = 0.5293                         Obs per group: min =         7
       between = 0.8184                                        avg =       7.0
       overall = 0.0749                                        max =         7
                                                F(7,17)            =  24869.12
corr(u_i, Xb)  = -0.9998                        Prob > F           =    0.0000
                          (Std. Err. adjusted for 18 clusters in commodityrun)
------------------------------------------------------------------------------
             |               Robust
       agtfp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         frt |   2.800851   .4872886     5.75   0.000     1.772762     3.82894
         psd |  -2.881551    .470496    -6.12   0.000    -3.874211   -1.888891
         irg |  -.0600163   .0101274    -5.93   0.000    -.0813832   -.0386494
          rd |   5.796523   1.555482     3.73   0.002     2.514743    9.078302
```

```
          te |   4.709384   1.422046     3.31   0.004      1.70913    7.709638
          to |  -.0380668   .0152813    -2.49   0.023    -.0703075   -.005826
         inf |   .0393121   .0244538     1.61   0.126     -.012281    .0909052
       _cons |  -4209.045   1094.412    -3.85   0.001    -6518.052   -1900.039
-------------+----------------------------------------------------------------
     sigma_u |  1823.8908
     sigma_e |  34.073497
         rho |  .99965111   (fraction of variance due to u_i)
```

Appendix A.4: Serial Autocorrelation Test

```
xtserial agtfp frt psd irg rd te to  inf
Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
    F(  1,      17) =      1.393
           Prob > F =      0.2542
```

Appendix A.5: Test for Cross-Sectional Dependence/Dontemporaneous Correlation

```
. xtcsd, pesaran abs
Pesaran's test of cross sectional independence =     1.814, Pr = 0.0700
Average absolute value of the off-diagonal elements =     0.408
```

Appendix A.6: Test for Endogeneity

```
ivregress 2sls agtfp psd inf irg rd te to ( frt = lfrt )
Instrumental variables (2SLS) regression               Number of obs =     125
                                                       Wald chi2(7)  =   18.12
                                                       Prob > chi2   =  0.0114
                                                       R-squared     =  0.1236
                                                       Root MSE      =  43.649
------------------------------------------------------------------------------
       agtfp |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         frt |  -.0002258   .0058977    -0.04   0.969     -.011785    .0113335
         psd |   .0088065   .0145601     0.60   0.545    -.0197308    .0373438
         inf |   .0410821   .0366132     1.12   0.262    -.0306785    .1128427
         irg |    .001404   .0054527     0.26   0.797    -.0092831    .0120911
          rd |   .0602568   .0238842     2.52   0.012     .0134447    .1070689
          te |   3.137331   2.873879     1.09   0.275    -2.495368     8.77003
          to |  -.0292054   .0205025    -1.42   0.154    -.0693895    .0109787
```

```
       _cons |  -2456.117   2315.581    -1.06   0.289    -6994.573    2082.338
-----------------------------------------------------------------------------
Instrumented:  frt
Instruments:   psd inf irg rd te to lfrt
. estat endogenous
  Tests of endogeneity
  Ho: variables are exogenous
  Durbin (score) chi2(1)          =  .995178  (p = 0.3185)
  Wu-Hausman F(1,116)             =  .930937  (p = 0.3366)
. ivregress 2sls agtfp frt inf irg rd te to ( psd = lpsd )
Instrumental variables (2SLS) regression               Number of obs =     125
                                                       Wald chi2(7)  =   24.52
                                                       Prob > chi2   =  0.0009
                                                       R-squared     =  0.1606
                                                       Root MSE      =  42.717
------------------------------------------------------------------------------
       agtfp |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         psd |  -.0081356   .0707155    -0.12   0.908    -.1467354    .1304642
         frt |   .0055405   .0039683     1.40   0.163    -.0022373    .0133183
         inf |   .0326144   .0362135     0.90   0.368    -.0383629    .1035916
         irg |  -.0038912   .0035712    -1.09   0.276    -.0108907    .0031083
          rd |   .0508505   .0245328     2.07   0.038     .0027672    .0989338
          te |   1.945701   2.994665     0.65   0.516    -3.923733    7.815136
          to |  -.0181087    .021798    -0.83   0.406    -.0608319    .0246146
       _cons |  -1536.431   2408.578    -0.64   0.524    -6257.156    3184.295
------------------------------------------------------------------------------
Instrumented:  psd
Instruments:   frt inf irg rd te to lpsd
. estat endogenous
  Tests of endogeneity
  Ho: variables are exogenous
  Durbin (score) chi2(1)          =  .17376  (p = 0.8951)
  Wu-Hausman F(1,116)             =  .16127  (p = 0.8992)
ivregress 2sls agtfp frt psd irg rd te to (  inf = linf  )
Instrumental variables (2SLS) regression               Number of obs =     125
```

```
                                                      Wald chi2(7)  =   23.83
                                                      Prob > chi2   =  0.0012
                                                      R-squared     =  0.1628
                                                      Root MSE      =  42.662
----------------------------------------------------------------------------
       agtfp |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+--------------------------------------------------------------
         inf |   .0155594   .0367599     0.42   0.672    -.0564888    .0876076
         frt |   .0051967   .0021545     2.41   0.016      .000974    .0094194
         psd |   .0007589   .0119022     0.06   0.949    -.0225689    .0240867
         irg |  -.0035975   .0020334    -1.77   0.077    -.0075829     .000388
          rd |   .0444953   .0224427     1.98   0.047     .0005083    .0884822
          te |   1.161273   2.689233     0.43   0.666    -4.109526    6.432072
          to |  -.0161007   .0178107    -0.90   0.366     -.051009    .0188077
       _cons |  -881.9238   2182.398    -0.40   0.686    -5159.346    3395.498
----------------------------------------------------------------------------
Instrumented:  inf
Instruments:   frt psd irg rd te to linf
. estat endogenous
  Tests of endogeneity
  Ho: variables are exogenous
  Durbin (score) chi2(1)          =   2.6861  (p = 0.1012)
  Wu-Hausman F(1,116)             =  2.54744  (p = 0.1132)
. ivregress 2sls agtfp frt psd inf rd te to (   irg = lirg )
Instrumental variables (2SLS) regression              Number of obs =     125
                                                      Wald chi2(7)  =   20.36
                                                      Prob > chi2   =  0.0048
                                                      R-squared     =  0.1108
                                                      Root MSE      =  43.966
----------------------------------------------------------------------------
       agtfp |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+--------------------------------------------------------------
         irg |   .0022549   .0172661     0.13   0.896    -.0315861    .0360959
         frt |  -.0008558   .0178664    -0.05   0.962    -.0358732    .0341616
         psd |   .0093439   .0276082     0.34   0.735     -.044767    .0634549
         inf |    .042443   .0443272     0.96   0.338    -.0444367    .1293228
```

```
          rd |   .0617358   .0360688     1.71   0.087    -.0089578    .1324294
          te |   3.324164   4.452409     0.75   0.455    -5.402397    12.05073
          to |  -.0309224   .0378149    -0.82   0.414    -.1050382    .0431933
       _cons |  -2600.869   3498.276    -0.74   0.457    -9457.365    4255.626
------------------------------------------------------------------------------
Instrumented:  irg
Instruments:   frt psd inf rd te to lirg
. estat endogenous
  Tests of endogeneity
  Ho: variables are exogenous
  Durbin (score) chi2(1)          =  .120233  (p = 0.7288)
  Wu-Hausman F(1,116)             =  .111683  (p = 0.7388)
. ivregress 2sls agtfp frt psd inf irg te to (   rd= lrd )
Instrumental variables (2SLS) regression               Number of obs =     125
                                                       Wald chi2(7)  =   18.96
                                                       Prob > chi2   =  0.0083
                                                       R-squared     =  0.1488
                                                       Root MSE      =  43.016
------------------------------------------------------------------------------
       agtfp |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          rd |   .0186339   .0303513     0.61   0.539    -.0408535    .0781214
         frt |   .0055878   .0021922     2.55   0.011     .0012912    .0098843
         psd |  -.0005239   .0120381    -0.04   0.965    -.0241182    .0230704
         inf |  -.0028894   .0419668    -0.07   0.945    -.0851428    .0793639
         irg |  -.0039794   .0020703    -1.92   0.055    -.0080372    .0000784
          te |  -1.131575   3.326301    -0.34   0.734    -7.651004    5.387855
          to |  -.0035355   .0204473    -0.17   0.863    -.0436116    .0365405
       _cons |   963.3438   2696.847     0.36   0.721     -4322.38    6249.068
------------------------------------------------------------------------------
Instrumented:  rd
Instruments:   frt psd inf irg te to lrd
. estat endogenous
  Tests of endogeneity
  Ho: variables are exogenous
  Durbin (score) chi2(1)          =  2.67032  (p = 0.1022)
```

```
  Wu-Hausman F(1,116)             =  2.53215  (p = 0.1143)

. ivregress 2sls agtfp frt psd inf rd irg to (   te = lte )

Instrumental variables (2SLS) regression              Number of obs =     125
                                                      Wald chi2(7)  =   25.72
                                                      Prob > chi2   =  0.0006
                                                      R-squared     =  0.1175
                                                      Root MSE      =    43.8

       agtfp |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          te |   9.089387   5.216486     1.74   0.081    -1.134738    19.31351
         frt |   .0042202   .0022826     1.85   0.064    -.0002537    .0086941
         psd |   .0039882   .0123654     0.32   0.747    -.0202476    .0282239
         inf |   .1000389   .0557186     1.80   0.073    -.0091675    .2092454
          rd |   .0994935   .0377721     2.63   0.008     .0254615    .1735255
         irg |  -.0026429   .0021592    -1.22   0.221    -.0068748     .001589
          to |  -.0523471   .0276895    -1.89   0.059    -.1066175    .0019234
       _cons |  -7316.637   4226.091    -1.73   0.083    -15599.62    966.3493
------------------------------------------------------------------------------
Instrumented:  te
Instruments:   frt psd inf rd irg to lte

. estat endogenous

  Tests of endogeneity
  Ho: variables are exogenous

  Durbin (score) chi2(1)          =  2.55942  (p = 0.1096)
  Wu-Hausman F(1,116)             =  2.42479  (p = 0.1222)

. ivregress 2sls agtfp frt psd inf rd  te  irg ( to= lto )

Instrumental variables (2SLS) regression              Number of obs =     125
                                                      Wald chi2(7)  =   23.98
                                                      Prob > chi2   =  0.0012
                                                      R-squared     =  0.1643
                                                      Root MSE      =  42.625
------------------------------------------------------------------------------
       agtfp |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          to |  -.0156788   .0200631    -0.78   0.435    -.0550018    .0236443
         frt |   .0052103   .0021663     2.41   0.016     .0009643    .0094563
```

```
        psd |   .0006906   .0119169     0.06   0.954    -.0226661    .0240473
        inf |   .0305404   .0358096     0.85   0.394    -.0396451    .1007258
         rd |   .0492352   .0230324     2.14   0.033     .0040925    .0943778
         te |   1.711508    2.79893     0.61   0.541    -3.774294     7.19731
        irg |  -.0036104   .0020455    -1.77   0.078    -.0076195    .0003987
      _cons |  -1358.796   2255.432    -0.60   0.547    -5779.362     3061.77
------------------------------------------------------------------------------
Instrumented:  to
Instruments:   frt psd inf rd te irg lto
. estat endogenous
  Tests of endogeneity
  Ho: variables are exogenous
  Durbin (score) chi2(1)          =  .185405  (p = 0.6668)
  Wu-Hausman F(1,116)             =  .172312  (p = 0.6788)
```

Appendix B: The standard CGE model of IFPRI

Appendix B.1: Definition of Sets, Parameters and Variables

Sets

AC	Global set for model accounts-aggregated micro-SAM accounts
$\alpha \in A$	activities
$\alpha \in ALEO(\subset A)$	activities with a Leontief function at the top of the technology nest
$c \in C$	commodities
$c \in CD(\subset C)$	commodities with domestic sales of domestic output
$c \in CDN (\subset C)$	commodities without domestic sales of output
$c \in CE(\subset C)$	exported commodities
$c \in CEN (\subset C)$	non-exported commodities
$c \in CM(\subset C)$	imported commodities
$c \in CMN(\subset C)$	non-imported commodities
$c \in CT (\subset C)$	transactions service commodities
$c \in CX (\subset C)$	commodities with domestic production
$f \in F$	factors
$i \in INS$	institutions (domestic and rest of the world)

i ∈ INSD(⊂ INS)	domestic institutions
i ∈INSDNG(⊂INSD)	domestic nongovernmental institutions
h∈ H(⊂ INSDNG)	households

Parameters (Latin Letters)

$ctws_c$	weight of commodity cin the CPI
$dwts_c$	weight of commodity cin the producer price index
ica_{ca}	quantity of cas intermediate input per unit of activity a
$icd_{cc'}$	quantity of commodity c as trade input per unit of c′ produced and sold domestically
$ice_{cc\prime}$	quantity of commodity c as trade input per exported unit of c′
$icm_{cc\prime}$	quantity of commodity c as trade input per imported unit of c′
$int\ \alpha_\alpha$	quantity of aggregate intermediate input per activity unit
$iva\ _\alpha$	Quantity of value-added per activity unit
$\overline{mps}_i$	base savings rate for domestic institution i
$mps01\ _c$	0-1 parameter with 1 for institutions with potentially flexed direct tax rates
$pwe\ _c$	Export price (foreign currency)
$pwm\ _c$	Import price (foreign currency)
$pwe\ _c$	quantity of stock change
$\overline{qg}_c$	base year quantity of government demand
$\overline{qinv}_c$	Base year quantity of private investment demand
$shif\ _{if}$	share for domestic institution i in income of factor f
$shii\ _{ii}$	Share of net income of i' to i (i'∈INSDNG' ; i∈INSDNG)
$\overline{tins}_i$	Exogenous direct tax rate for domestic institution i
$tins01\ _i$	0 1 parameter with 1 for institutions with potentially flexed direct tax rates
$tm\ _c$	import tariff rate
$tq\ _c$	Rate of sales tax
$trnsfr\ _{if}$	Transfer from factor f to institution i

Parameters (Greek Letters)

α_a^{va} Efficiency parameter in the CES value – added function

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

α_a^{q} Armington function shift parameter

α_c^{t} CET function shift parameter

β_{ach}^{h} Marginal share of consumption spending on home commodity c from activity α for household h

β_{ch}^{m} Marginal share of consumption spending on marketed commodity c for household h

δ_{ac}^{ac} share parameter for domestic commodity aggregation function

δ_c^{q} Armington function share parameter

δ_c^{t} CET function share parameter

δ_{fa}^{va} CES value – added function share parameter for factor f in activity α

γ_{ch}^{m} subsistence consumption of marketed commodity c for household h

γ_{ach}^{h} subsistence consumption of home commodity c from activity α for household h

θ_{ac} yield of output c per unit of activity α

ρ_a^{va} CES value – added function exponent

ρ_c^{ac} domestic commodity aggregation function exponent

ρ_c^{a} Armington function exponent

ρ_c^{t} $CET\ function\ exponent$

Exogenous Variables

$\overline{DMPS}$ change in domestic institution savings rates (0 for base; exogenous variable)

$\overline{DPI}$ producer price index for domestically marketed output

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

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

$\overline{\text{YG}}$ government revenue

$\overline{GADJ}$ government consumption adjustment factor

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

$\overline{QFS}_f$ quantity supplied of factor

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

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

$\overline{TINS}_i$ direct tax rate for institution i (i ∈ INSDNG)

$\overline{MPS}_i$ marginal propensity to save for domestic non − government institution

Endogenous Variables

$LADJ$ investment adjustment factor

CPI consumer price index

EG government expenditure

EH_h consumption spending for household

EXR exchange rate (LCU per unit of FCU)

$GOVSHR$ government consumption share in nominal absorption

$GSAV$ government savings

$INVSHR$ investment share in nominal absorption

PA_α activity price (unit gross revenue)

PDD_c demand price for commodity produced and sold domestically

PDs_c supply price for commodity produced and sold domestically

PE_c export price (domestic currency)

$PINTA_\alpha$ aggregate intermediate input price for activity α

PM_C import price (domestic currency)

PQ_C composite commodity price

PVA_α value − added price (factor income per unit of activity)

PX_c aggregate producer price for commodity

$XAC_{\alpha c}$ producer price of commodity cfor activity α

QA_{α} quantity (level) of activity

QD_{C} quantity sold domestically of domestic output

QE_{C} quantity of exports

$QF_{f\alpha}$ quantity demanded of factor f from activity α

QG_{c} government consumption demand for commodity c

QH_{ch} quantity consumed of commodity c by household h

$QHA_{\alpha ch}$ quantity of household home consumption of commodity c from activity α for household h

$QINTA_{\alpha}$ quantity of aggregate intermediate input

$QINT_{c\alpha}$ quantity of commodity c as intermediate input to activity α

$QINV_{c}$ quantity of investment demand for commodity c

QM_{c} quantity of imports of commodity c

QQ_{c} quantity of goods supplied to domestic market (composite supply)

QT_{c} quantity of commodity demanded as trade input

QVA_{α} quantity of (aggregate) value − added

QX_{C} aggregated marketed quantity of domestic output of commodity c

$QXAC_{ac}$ quantity of marketed output of commodity c from activity a

$TABS_{ac}$ quantity of marketed output of commodity c from activity a

$TABS$ total nominal absorption

$TRII_{ii'}$ transfers from institution i′ to i (both in the set INSDNG)

WF_{f} average price of factor f

YF_{f} income of factor f

YI_{i} income of domestic nongovernment institution

YIF_{if} income to domestic institution i from factor f

Appendix B.2: Equations of the Model

STATIC PART

Price Block

[1] Import price

$PM_c = pwm_c(1 + tm_c) * EXR + \sum_{c' \in CT} PQ_{c'} * icm_{c'c}$ $c \in CM$

[2] Export price

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

[3] Demand price of domestic non-traded goods

$\mathrm{PDD_c = PDS_c + \sum_{c' \in CT} PQ_{c'} \cdot icd_{c'c}}$ $c \in CD$

[4] Absorption

$\mathrm{PQ_c \cdot (1 - tq_c) \cdot QQ_c = PDD_c \cdot QD_c + PM_c \cdot QM_c}$ $\mathrm{c \in (CD \cup CM)}$

[5] Marketed output value

$\mathrm{PX_c \cdot QX_c = PDS_c \cdot QD_c + PE_c \cdot QE_c}$ $\mathrm{c \in CX}$

[6] Activity price

$PA_\alpha = \sum_{c \epsilon C} PXAC_{ac} \cdot \theta_{\alpha c}$ $\alpha \in A$

[7] Aggregate intermediate input price

$\mathrm{PINTA_\alpha = \sum_{c \epsilon C} PQ_c \cdot ica_{c\alpha}}$ $\alpha \in \mathrm{A}$

[8] Consumer price index

$\mathrm{CPI = \sum_{c \epsilon C} PQ_c \cdot cwts_c}$

[9] Producer price index for non-traded market output

$\mathrm{\overline{DPI} = \sum_{c \epsilon C} PDS_c \cdot dwts_c}$

Production and Trade Block

[10] Leontief technology: Demand for aggregate value-added

$\mathbf{QVA_\alpha = iva_\alpha \cdot QA_\alpha}$ $\boldsymbol{a \in ALEO}$

[11] Leontief technology: Demand for aggregate intermediate input

$\boldsymbol{QINTA_\alpha = inta_\alpha \cdot QA_\alpha}$ $\boldsymbol{a \in ALEO}$

[13] Value-added and factor demand

$$QVA_a = \alpha_a^{va}\left(\sum_{f\in F}\delta_{fa}^{va}.QF_{fa}^{-\rho_a^{va}}\right)^{\frac{1}{\rho_a^{va}}} \qquad a \in A$$

[14] Factor Demand

$$WF_f.\overline{WFDIST}_{fa} = PVA_a.QVA_a\left(\sum_{f\in F'}\delta_{fa}^{va}QF_{fa}^{-\rho^{va}\ a}\right).\delta_{fa}^{va}QF_{fa}^{-\rho^{va}\ a^{-1}} \qquad a \in A; f \in F$$

[15] Disaggregated intermediate input demand

$$QINT_{ca} = ica_{ca}.QINTA_a \qquad a \in A; c \in C$$

[16] Commodity production and allocation

$$QXAC_{ac} + \sum_{h\in H} QHA_{ach} = \theta_{ac}.QA_A \qquad a \in A; a \in CX$$

[17] Output aggregation function

$$QX_c = \alpha_c^{ac}\left(\sum_{a\in A}\delta_{ac}^{ac}.QXAC_{ac}^{-\rho^{ac}c}\right)^{-\frac{1}{\rho_c^{ac}-1}} \qquad c \in CX$$

[18] First-order condition for output aggregation function

$$PXAC_{ac} = PX_c.QX_c\left(\sum_{a\in A}\delta_{ac}^{ac}.QXAC_{ac}^{-\rho^{ac}c}\right)^{-1}.\delta_{ac}^{ac}.QXAC_{ac}^{-\rho^{ac}c^{-1}} \qquad a \in A; c \in CX$$

[19] Output transformation (CET) function

$$QX_c = \alpha_c^t\left(\delta_c^t \cdot QE_c^{\rho_c^t} + (1-\delta_c^t)\cdot QD_c^{\rho_c^t}\right)^{\frac{1}{\rho_c^t}} \qquad c\epsilon(CE \cap CD)$$

[20] Export-domestic supply ratio

$$\frac{QE_c}{QD_c} = \left(\frac{PE_c}{PDS_c}\cdot\frac{1-\delta_c^t}{\delta_c^t}\right)^{\frac{1}{\rho_c^t-1}} \qquad c\epsilon(CE \cap CD)$$

[21] Output transformation for non-exported commodities

[22] Composite supply (Armington) function

$$QQ_c = \alpha_c^q\cdot\left(\delta_c^q\cdot QM_c^{-\rho_c^q} + \left(1-\delta_c^q\right)\cdot QD_c^{-\rho_c^q}\right)^{\frac{1}{\rho_c^q}} \qquad c\epsilon(CM \cap CD)$$

[23] Import-domestic demand ratio

$$\frac{QM_c}{QD_c} = \left(\frac{PDD_c}{PM_c}\cdot\frac{\delta_c^q}{1-\delta_c^q}\right)^{\frac{1}{1+\rho_c^q}} \qquad c\epsilon(CM \cap CD)$$

[24] Composite supply for non-imported outputs and non-produced imports

$$QQ_c = QD_c + QM_c \qquad c\epsilon(CD \cap CMN) \cup (CM \cup CDN)$$

[25] Demand for transaction services

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

Institutional Block

[26] Factor income

$$\mathrm{YF_f} = \sum_{a\epsilon A} \mathrm{WF_f} \cdot \overline{\mathrm{WFDIST_{fa}}} \cdot \mathrm{QF_{fa}} \qquad f\epsilon F$$

[27] Institutional factor income

$$YIF_{if} = shif_{if} \cdot \left[\left(1 - tf_f\right) \cdot YF_f - trnsfr_{rowf} \cdot EXR\right] \qquad i\epsilon INSD; f\epsilon F$$

[28] Income of domestic, non-government institutions

$$\mathrm{YI_i} = \sum_{f\epsilon F} \mathrm{YIF_{if}} + \sum_{i' INSDNG;} \mathrm{TRII_{ii'}} + \mathrm{trnsfr_{gov}} \cdot \overline{\mathrm{CPI}} + \mathrm{trnsfr_{irow}} \cdot \mathrm{EXR} \qquad \mathrm{i} \in \mathrm{INSDNG}$$

[29] Intra-institutional transfer

$$\mathrm{TRII_{ii\prime}} = \mathrm{shii_{ii\prime}}.(1 - \mathrm{MPS_h})(1 - \mathrm{TINS_h}).\mathrm{YI_h} \qquad \mathrm{h} \in \mathrm{H}$$

[30] Household consumption expenditure $h\epsilon H$

$$\mathrm{EH_h} = (1 - \sum_{i\epsilon INSDNG} \mathrm{shii_{ih}}) \cdot (1 - \mathrm{MPS_h}) \cdot (1 - \mathrm{TINS_h}) \cdot \mathrm{YI_h}$$

[31] Household consumption demand for marketed commodities

$$\mathrm{PQ_c} \cdot \mathrm{QH_{ch}} = \mathrm{PQ_c} \cdot \gamma^{m}_{ch} + \beta^{m}_{ch} \cdot \left(\mathrm{EH_h} - \sum_{c' \varepsilon C} \mathrm{PQ'_c} \cdot \gamma^{m}_{c'h} - \sum_{a\epsilon A} \sum_{c'\epsilon C} \mathrm{PXAC_{ac'}} \cdot \gamma^{h}_{ac'h}\right) \quad c\epsilon C; h\epsilon H$$

[32] Household consumption demand for home commodities

$$\mathrm{PXAC_{ac}}.\mathrm{QHA_{ach}} = \mathrm{PXAC_{ac}}.\gamma^{h}_{ach} + \beta^{h}_{ach}.\left(\mathrm{EH_h} - \sum_{c' \in C} \mathrm{PQ_c}.\gamma^{M}_{c'h} - \sum_{a \in A} \sum_{c' \in C} \mathrm{PXAC_{ac'}}.\gamma^{h}_{ac'h}\right) \qquad \mathrm{a} \in \mathrm{A}$$

[33] Investment demand

$$QINV_c = \overline{LADJ} \cdot \overline{qinv_c} \qquad c\epsilon CINV$$

[34] Government consumption demand

$$QG_e = \overline{GADJ} \cdot \overline{qg_e} \qquad c\epsilon C$$

[35] Government revenue

$$\mathrm{YG} = \sum_{i\epsilon INSDNG} \mathrm{TINS_i} \cdot \mathrm{YI_i} + \sum_{c\epsilon CM} \mathrm{tm_c} \cdot \mathrm{pwm_c} \cdot \mathrm{QM_c} \cdot \mathrm{EXR} + \sum_{c\epsilon C} \mathrm{tq_c PQ_c QQ_c} + \sum_{f\epsilon F} \mathrm{yif_{govf}} + \mathrm{trnsfr_{govrow}} \cdot \mathrm{EXR}$$

[36] Government expenditure

$$EG = \sum_{c \epsilon C} PQ_c \cdot QG_c + \sum_{i \epsilon INSDNG} trnsfr_{igov} \cdot CPI$$

System Constraint Block

[37] Factor market

$$\sum_{a \epsilon A} QF_{fa} = \overline{QFS_f} \qquad c \epsilon C$$

[38] Composite commodity market

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

[39] Current account balance for the rest of the world (in foreign currency)

$$\sum_{c \epsilon CM} pwm_c . QM_c + \sum_{f \epsilon F} trnsfr_{rowf} = \sum_{c \epsilon CE} pwe_c \cdot QE_c + \sum_{i \epsilon INSD} trnsfr_{irow} + \overline{FSAV}$$

[40] Government balance

$$YG = EG + GSAV$$

[41] Direct institutional tax rates

$$TINS_i = \overline{tins_i}.\left(1 + \overline{TINSADJ}.TINS01_i\right) + DMPS.mps01_i \qquad i \in INSDNG$$

[42] Institutional savings rates

$$MPS_i = \overline{mps_i}.\left(1 + \overline{MPSADJ}.mps01_i\right) + \overline{DTINS}.TINS01_i \qquad i \in INSDNG$$

[43] Saving-investment balance

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

[44] Total absorption

$$TABS = \sum_{h \in H} \sum_{c \in C} PQ_c . QH_{ch} + \sum_{a \in A} \sum_{c \in C} \sum_{h \in H} PXAC_{ac} . QHA_{ach} + \sum_{c \in C} PQ_c . QG_c + \sum_{c \in C} PQ_c . QINV_c + \sum_{c \in C} PQ_c . qdst_c$$

[45] Ratio of investment to absorption

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

[46] Ratio of government consumption to absorption

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

[47] Government share

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

[48] Investment share

$$GOVSHR.(TABS) = \sum_{c \in C} PQ_c.QG_C$$

DYNAMIC PART

[49] Average capital rental rate

$$AWF_{ft}^{a} = \sum_{a} \left[\left(\frac{QF_{fat}}{\sum_{a'} QF_{fa't}} \right) . WF_{ft}.WFDIST_{fat} \right]$$

[50] Share of new capital

$$\eta_{fat}^{a} = \left(\frac{QF_{fat}}{\sum_{a'} QF_{fa't}} \right) . \left(\beta^{a} \left(\frac{WF_{ft}.WFDIST_{fat}}{AWF_{ft}^{a}} - 1 \right) + 1 \right)$$

[51] Quantity of new capital by sector

$$\Delta K_{fat}^{a} = \eta_{fat}^{a} \left(\frac{\sum_{a} PQ_{ct}.QINV_{ct}}{PK_{ft}} \right)$$

[52] Unit price of capital

$$PK_{ft} = \sum_{c} PQ_{ct} \frac{QINV_{ct}}{\sum_{c'} QINV_{c't}}$$

[53] Average Price of capital

$$QFS_{fat+1} = QFS_{fat}. \left(1 + \frac{\sum_{a} \Delta K_{fat}}{QFs_{ft}} - v_f \right)$$

[54]   Average quantity demanded of factor *f* from activity *a*

$$QFf_{ft+1} = QF_{fat}. \left(1 + \frac{\Delta K^{a}{}_{fat}}{QF_{fat}} - v_f \right)$$