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THE ECONOMY-WIDE IMPACT OF INVESTMENT ON INFRASTRUCTURE FOR ELECTRICITY IN ETHIOPIA: A RECURSIVE DYNAMIC COMPUTABLE GENERAL EQUILIBRIUM APPROACH

BY

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The Economy Wide Impact of Investment on Infrastructure for Electricity in Ethiopia: A Recursive Dynamic Computable General Equilibrium Approach

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This is to certify that the thesis prepared by Dinkneh Gebre Borojo, entitled: *The Economy - Wide Impact of Investment on Infrastructure for Electricity in Ethiopia: A Recursive Dynamic Computable General Equilibrium Approach* and submitted in partial fulfilment of the requirements for the Degree of Masters of Science in Economics (Economic Policy Analysis) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Abstract

The Economy-Wide Impact of Investment on Infrastructure for Electricity in Ethiopia: A Recursive Dynamic CGE Approach

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Addis Ababa University, 2012

In current periods Ethiopia has been implementing huge investment on electricity. The studies on the economic impact of this investment conducted so far, however, are not sufficient and no study is conducted by using a recursive dynamic CGE model. To this effect, the study used a recursive dynamic CGE model. The model used an updated version of 2005/06 SAM. The simulations examined to explore the impact of this investment on Ethiopian economy are investment on electricity fully financed by foreign saving (loan), investment on electricity fully financed by domestic households and enterprise saving, and investment on electricity partly financed by domestic household and enterprise saving and partly by foreign saving. We run these simulations in combination with increase in TFP of industrial and service sectors.

The findings of the study have shown the improvement of the real GDP, output of industrial and service sectors, average factor income and household income. However, the high growth of real GDP is registered when the investment on electricity is fully financed by domestic household and enterprise saving and when this investment is partly financed by domestic non government institutions and partly by foreign saving. Household consumption and consumption expenditure have raised more when investment on electricity is financed by increased foreign savings. However, they have grown at negative rate when the investment is fully financed with increased domestic household and enterprise saving. In general, investment on electricity fully financed by foreign saving is resulted in lower growth rate of real GDP due to worsening of the net export and it is also expected to be repaid that would increase indebtedness of the country. On the other hand, meeting this investment with domestic household and enterprise saving will be difficult. So, financing investment on electricity partly by domestic household and enterprise saving and partly by foreign saving would be worthwhile.

Keywords: Investment, Electricity, Recursive dynamic CGE, Ethiopia

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List of Acronyms

CGE	Computable General Equilibrium Model
CPI	Consumer Price Index
DPI	Producer Price Index
EDRI	Ethiopian Development and Research Institute
EEA	Ethiopian Economic Association
ERG	Ethio Resource Group
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
GTP	Growth and Transformation Plan
GIZ	German Technical Cooperation
GW	Giga Watt
GWH	Giga Watt Hour
KWH	Kilo Watt Hour
MoFED	Ministry of Finance and Economic Development
MoWE	Ministry of Water and Energy
MW	Mega Watt
NMSA	National Meteorological Services Agency
OECD	Organization for Economic Cooperation and Development
TFP	Total Factor Productivity
TOE	Tons of Oil Equivalent
SAM	Social Accounting Matrix
VAT	Value Added Tax
UNDP	United Nations Development Program
UNIDO	United Nations Industrial Development Program
WAPCO	Water and Power Consultancy Services
WDI	World Development Indicator
WTO	World Trade Organization

CHAPTER ONE

INTRODUCTION

1.1. Background of the study

That energy is a critical economic commodity and an adequate and reliable supply of energy is a prerequisite for economic development is well appreciated (UNIDO, 2009). Compared to other parts of the world, however, energy deprivation or the lack of access to it is by far most prevalent in Africa. Energy endowments remain largely underutilized. For instance, only 5% of the continent's potential of hydropower and 0.6 % of geothermal has been exploited. The gap between supply and demand in Africa has been widening over time, resulting in the lowest per capita consumption average of 0.66 tons of oil equivalent (TOE) compared to the global average of 1.8 TOE in 2008. Recent trends indicate that over 60% of Sub-Saharan Africans will still not have access to electricity by 2020 (UNIDO, 2009).

Ethiopia is endowed with enormous water, solar, wind and geothermal energy potentials: of which 84% is from hydropower (estimated to be 30 to 45 GW), 13% is from wind and 3% is from different sources. However, only a fraction of this potential has been used so far (ERG, 2009). As a result, it has extremely low energy consumption average per capita (36 KWH) per year.

Hydropower development in Ethiopia started with mini to small power plants. The current and planned development in the sector is, however, almost exclusively focusing on large plants. Harnessing hydropower to generate electricity has the potential for ensuring energy security and green development path (MoWE, 2012).

For the last seven years, Ethiopia faced unmet energy demand. In 2009, the country was plagued by power shortage. As a result, considerable potential output has been lost due to power cuts in the past few years (Ermias et al, 2010). We could presume that left unattended, potential losses from power disruption will increase in the future, as the relative contributions of the industrial sector increase in the economy.

To narrow the gap between power supply and demand, and hence avoid losses, the government is engaged in implementing an ambitious investment plan that aims to expand the power system and quadruple it before 2016 (ERG, 2009). Once the largest hydropower and wind projects are completed in 2016, the installed capacity of the country will be more than 11 GW compared to the less than 2 GW in 2010. The construction of these large dams is foreseen in the plan that aims to bring capacity to 19 GW after 2019. To meet this ambitious investment it would require average spending more than 30 billion birr per year (EEPCo, 2011).

1.2. Statement of the Problem

Ethiopia has an untapped large potential for hydropower development. Its generation capacity is estimated at 45,000 MW. However, so far, the utilization level has been limited to 2 GW, which is less than 4.5 % of the existing potential. Similarly, solar and wind potentials have been researched and found to be considerable (Bekele et al, 2009; Bekele et al, 2010; Wolde-Ghiorgis, 1988; Mulugetta et al, 1996) but no substantial development has been made so far. Most of the population in the country lives in poverty and uses traditional fuels such as fire wood that deplete forest resources and aggravate soil erosion.

At the national level it is estimated that biomass fuels meet 88 % of total energy consumed in the country.

The available power capacity in Ethiopia is not able to accommodate demand. Demand for electricity is growing at 14% from 2005 onwards (ERG, 2009). It will grow at 17% under 10% GDP growth and 32% under 14.9% GDP growth scenarios (Zenebe and Alemu, 2011). The steep increase in demand reflects both the growing electrification of the country and rapid growth of electricity-intensive industries i.e. Power demand will increase in the future as the economy grows and the relative contributions of the industrial sector increases. To increase supply of energy as rapidly as growth in demand, the Government of Ethiopia has given commitment to develop the electric power generating capacity of the country by investing on the available water and wind energy resources in the country (EEPCO, 2010). Accordingly, Ethiopia is constructing large hydropower dams and wind projects to accommodate domestic demand and to export to neighbouring countries.

Investment on large dams are not, however, free from criticisms. There are two views among scholars. One group believes that large dams are opened to public scrutiny and political benefit with widespread debate on performance, benefits and negative impacts such as debt burden, cost overruns, displacement and impoverishment of people (Parasuraman et al, 2001). For others, constructing large dams is the essence of modernisation and effective intervention for irrigation, electricity, flood control and water supply accounting for a large share of public investment in most countries. It is argued that it contributes for economic development through job creation, fostering an industrial base with export capability; triggering economic growth (Sambo, 2005; Aydin, 2010; Girma, 2000, and Parasuraman et al, 2001).

In addition to triggering economic growth, investment on hydropower energy has cost advantages. In light of recent high and volatile oil prices, renewable energy including hydropower has emerged as a viable option at most places to address energy challenges (UNIDO, 2009). Hydro and wind power could save scarce resources of imported oil for essential purposes and relieve pressures on forest reserves (Fergus, 1983) and is central to the mission for sustainable development.

In Ethiopia a few studies have been conducted on economic impact of this investment. The studies on the economy wide impact of investments on infrastructure for electricity conducted so far, however, are not sufficient, not without limitations and no study is conducted by using A Recursive Dynamic Computable General Equilibrium Model.

Ermias et al (2011) in their study "Does electricity strategy matter? Shortage and investment: reflections based on CGE analysis", they used static CGE analysis to show the impact of electricity shortage on economic growth and economic impact of investment on electricity. They used electricity rationing scenarios among different economic sectors and investment on electricity. The method they used (static CGE) shows one time effect of policy changes but is unable to account for growth or second effects (Annabi et al, 2004). The effects of change in infrastructure investments are dynamic and cannot be sufficiently analysed by static CGE models.

Zenebe and Alemu (2011) in their study "Sustainable financing of Ethiopia's energy infrastructure: an economic analysis" examined current financing mechanisms and implications of planned infrastructure investments on the country's outstanding debt by using indicator method and ratio analysis.

Analysis of the economy wide impact of investments on infrastructure for electricity involves taking into account the economy wide effects of policy, because the introduction of a single shock will have impact on various economic activities as electricity is an intermediate input for almost all activities in the production process.

Partial equilibrium models, econometric models and/or static CGE models are inappropriate to deal with such kind of investment shocks. They do not provide good understanding of multiple linkages through which investment on infrastructure for electricity affects the economy and do not provide an adequate framework to outline the transmission mechanisms of the economy wide impact that we need to understand (Dissou et al, 2011). Furthermore, they do not allow for analysis of general equilibrium feedback impact of investment on infrastructure for electricity and its fiscal implications.

Therefore, this paper aims to fill this gap by trying to address the limitations described above by using a recursive dynamic CGE Model which is believed to be best suited to assess the impact of investment on infrastructure for electricity. Thus, the aim of this paper is to analyse the economy wide impact of investment on infrastructure for electricity by analysing its impact on macroeconomic variables of interest such as GDP, real consumption, real investment, exports and imports, trade balance, sectoral indicators, factor income, and household income and consumption expenditure under different financing options.

1.3. Objectives of the Study

The general objective of this study is to assess the economy wide impact of investment on infrastructure for electricity by using recursive dynamic CGE model.

The specific objectives are to analyse the impact of investment on electricity on:

- Macroeconomic variables
- Sectoral output
- trade balance (exports, imports)
- Households income,
- Household consumption expenditure and
- Factor income

1.4. Significance of the Study

Given the importance of energy sector in Ethiopian economy, the findings of this study will provide an important link on how to design policy; will help inform policy makers whether or not the desired outcome of electricity investment is being realized. In addition, the study will provide a good basis for further research on economic impact of investment on infrastructure for electricity in Ethiopia.

1.5. Scope of the Study

This study focuses on the impact of investment on infrastructure on energy particularly investment on electricity.

1.6. Limitation of the Study

We used elasticity of TFP with respect to investment on electricity estimated to analyse the impact of infrastructure spending in Mali. We did not estimate elasticity of TFP with respect to investment on electricity in Ethiopia.

1.7. Organization of the Paper

The paper is organized as follows: chapter one discusses introduction and chapter two treats theoretical and empirical literature reviews. Chapter three gives an overview of Ethiopian economy and energy sector. Chapter four gives methodology of the study and chapter five presents results and findings of the study and policy simulations finally, chapter six concludes and forward policy implications.

CHAPTER TWO

LITERATURE REVIEW

2.1. Theoretical Literature

2.1.1. Introduction

Different disciplines use the term "energy" differently. In physical science, "energy" is the capacity for doing work. In economics, "energy" includes all energy resources or commodities that embody significant amounts of physical energy and thus offer the ability to perform work. Energy commodities - e.g. gasoline, diesel, natural gas, propane, coal, or electricity can be used to provide energy services for human activities (Sweeney, undated).

Energy can be classified in at least two ways so that we have: traditional and modern energies, and renewable and non-renewable energies. The term traditional energy is used to denote locally collected and often unprocessed biomass based fuels, such as crop residues, wood and animal dung. Most traditional energy is used non-commercially while modern energy refers a variety of commercial forms of energy such as liquefied petrol gas, kerosene, petrol, and electricity (connected to grids or independent of grids), and bio energy. But this expression is used very broadly, and has no international definition.

Renewable energy consists of energy produced and/or derived from sources infinitely renovated or generated by combustible renewable sources. Renewable energy sources capture their energy from existing flows of energy, from on-going natural processes, such as sunshine, wind, flowing water (hydropower), biomass and geothermal heat flow (FAO, 2000). On the other hand, non-renewable energy is that form of energy obtained from sources that are that are finitely renovated (Gritsevskyi, 2007). All available sources of energy will be necessary, but for environmental reasons, the first priority should be the development of all the technically, economically and environmentally feasible potential from clean, renewable energy sources, such as hydropower (Budak et al, 2009).

There are numbers of literatures demonstrating that energy has significant positive effects on economic growth (Sambo, 2005; Stern, 2004; Mbanda et al, 2011; Morimoto, 2004; Enang, 2010). Energy is widely considered as one of the major drivers of economic growth. Adequate supply of energy improves production technology and hence productivity, and generate employment opportunities and income.

Investment on infrastructure for energy is one of the key determinants of supply of energy. Investment on energy in turn depends on introduction of new technology and public acceptance of the need for new infrastructure. There are different economic growth models considering energy as an input in the production of output differently. The following section gives a detailed picture about the significance of energy as an input in growth models.

2.1.2. Ecological Economics and Energy

Ecological economists derive their view of the role of energy in economic growth from the biophysical foundations of the economy. They believe that energy has a significant role in economic growth (Stern et al, 2004; Stern, 2010). Some ecological economists consider energy as a primary factor of production directed by capital and labor (Stern et al, 2004). They focus on the material basis of the economy and consider capital and labor as intermediate inputs (Hannon, 1973)

There are two fundamental properties of energy in thermodynamics (physical or conservation law). The first law states to obtain a given material output, a greater or equal amount of matter must be used in its production process as inputs. This condition shows the minimum material input including energy requirements for any production process producing material outputs. The second law of thermodynamics (the efficiency law) implies that a minimum quantity of energy is required to carry out the transformation of matter. All production involves the transformation or movement of matter in some way, and all such transformations require energy. Therefore, according to ecological economists energy is an important factor of production (Stern, 2004).

2.1.3. Mainstream Growth Theory and Energy

Mainstream growth theories consider capital, labor, and land as the only primary factors of production. They focus on the primary inputs, in particular on capital, labor and land, and pay little or indirect attention to the role of energy or other natural resources in promoting economic growth (Stern, 2003). The starting point for almost all analysis of growth in neoclassical framework is Solow growth model.

Solow growth model focuses on three inputs (capital, labor and technology) to produce output. Capital, labor and effectiveness of labor (technology) combined in the following function to produce output (Romer, 1996).

$$Y(t) = F(K(t), A(t)L(t)) \quad \text{-- --------} \quad (2.1)$$

Where, Y(t) - output, K(t) -capital stock, A(t)-technology and L(t) –labor, $A(t)L(t)$ -effective labor

According to this model the amount of output obtained from units of inputs (capital and labor) increases over time and there is technological progress only if the amount of knowledge increases. Technological progress is labor augmenting or Harrod neutral. The model is based on the assumption that the production function possesses constant returns to scale in its two arguments capital and effective labor. The model does not include inputs other than capital and labor. It considers other inputs like land, energy and other natural resources are less important in the production process (Romer, 1996).

2.1.4. The linkage of Economic Growth Models and Energy

The mainstream growth models in the previous section do not include energy resources as one of the essential determinants of growth. Arbex et al (2010) integrated a neoclassical growth model originated by Solow (1956) and input-output analysis developed by Leontief in late 1920s to analyse energy consumption and economic growth for Brazil, where final demand is the key link between the models. They used the Cobb-Douglas production function that includes natural resources and integrate with input- output model. The production function is given as:

$$Y_{it} = A_{it} K_{it}^{\alpha i} L_{it}^{\beta i} T_{it}^{\delta i} \text{ -- ------- (2.2)}$$

Where Y_{it} is sectoral output, A_{it} is technology, L_{it} is labor, K_{it} is capital, and T_{it} stands for energy, αi, βi, $\delta i > 0$ and $\alpha i + \beta i + \delta i = 1$. They assumed the production function displays constant returns to scale. Total factor productivity for each economic sector changes overtime at constant rate i.e. the total factor productivity A_{it} for each economic sector changes over time at a constant rate, i.e. $A_{it}+1 = (1+g_{Ai})A_{it}$ (Arbex et al,2010).Where, g_{Ai} is exogenous growth rate of total factor productivity in sector i.

Sectoral output is equal to aggregate demand of the economy which is the sum of aggregate consumption (C_t), aggregate investment (I_t), government consumption (G_t) and net export (NE_t) ($F_t = C_t + I_t + G_t + NE_t = Y_t$). If this aggregate demand is represented by F, then demand for energy can be expressed by using central input-output model ($X_t=A_tX_t + F_t$):

$$TE_t = P_t[I - A_t]^{-1} F \quad \text{Or} \quad TE_t = P_t[I - A_t]^{-1} Y_t \text{ ------------------------------------ (2.3)}$$

Where, TE_t is vector of total sectoral energy consumption and P_t is (m x m) energy consumption coefficients matrices and A_t is (m x m) input output coefficient matrix. This integration is based on the input-output model framework which allows considering transactions i.e. payments and income received using the following identities.

$X_t = A_tX_t + F_t$ -- ----------------- ---- (2.4)

Where, X_t is an (m x 1) vector of sectoral output, F_t is an (m x1) vector of final demand A_t is an (m x m) input-output coefficients matrix

So based on neoclassical growth model and Leontief input-output models integration, consumption of energy as an input in output production can be forecasted (Arbex et al, 2010).

In the same way, Stern (2010) integrated different approaches and added energy as an input in the growth model by modifying Solow's model, allowing substitutability between capital and labor to remain unity and low substitutability of energy with capital and labor. In this setup energy can be either constraint on growth or an enabler of growth based on availability of energy and technological change. Omitting time indices for simplicity, the model consists of two equations:

$$Y = \left[(1-\gamma)\left(A_L{}^{\beta} L^{\beta} K^{1-\beta}\right)^{\phi} \gamma \left(A_E E\right)^{\phi}\right]^{1/\phi} \text{ -- (2.5)}$$

$$\Delta K = s(Y - P_E E) - \delta K \text{ -- (2.6)}$$

Equation (2.5) embeds a Cobb-Douglas function of capital (K) and labor (L) in a CES function of value added and energy (E) to produce gross output Y. P_E is the price of energy and γ is a parameter reflecting the relative importance of energy and value added. A_L and A_E are the augmentation indices of labor and energy. Equation (2.6) is the equation of motion for capital that assumes like Solow (1956) that the proportion of gross output that is saved is fixed at *s* and that capital depreciates at a constant rate $\phi = (\sigma - 1)/\sigma$, where, σ - is elasticity of substitution between energy and the value added aggregates

For Stern (2010), economic growth that creates jobs and raises incomes depends on greater and more efficient use of energy.

2.1.5. Energy Consumption and Economic Growth

The previous section established that energy is one of essential inputs and in the long run its availability could constrain economic growth. This section examines the factors that could reduce or strengthen the linkage between energy use and economic activity over time. Energy is linked to economic activity in so many complex ways that makes it difficult to unravel the overall puzzle and isolate the individual elements. Demand for energy is derived demand, that is, it arises because of the level of income, tastes, expectations concerning other goods and services whose production in turn depends on energy, and substitution between different types of energies (Munasinghe et al, 1993).

GDP growth is a critical determinant of the demand for energy. As a result, growth projections are essential for estimating future demand and supply of energy. After the energy demand estimates are done energy supply, investment, and prices are in turn derived. The energy and macro economy have forward and backward linkages: macroeconomic impacts on energy sector which is forward linkage and energy sector impact on national economy which is backward linkage (Munasinghe, et al, 1993). From the forward linkage we can forecast energy demand by using an input-output framework mentioned in the equation (2.3). Accordingly, we can link energy demand and output as follows:

$$TE_{t+1} = P_t\left[I - A_t\right]^{-1} Y_{t+1} \text{ ---------------- (2.7)}$$

Where, TE_{t+1} total energy demand in t+1 and Y_{t+1} Aggregate output in period t+1.

In the other way we can represent production function as follows,

$$(Q_1, \ldots, Q_m)' = f(A, X_1, \ldots, X_n, E_1, \ldots, E_p) \text{ ---------------- (2.8)}$$

Where, the Q_i are various outputs, such as manufactured goods and services, the X_i are various inputs such as capital, labor, the E_i are different energy inputs and A is the state of technology as defined by the total factor productivity indicator (Stern,2010). The relationship between energy and an aggregate output such as gross domestic product can then be affected by: substitution between energy (E_i) and other inputs (X_i), technological change-a change in A, shifts in the composition of the energy input (E_i), as well as shifts in the composition of output (Q_i) (Ibid).

2.1.6. Infrastructure Investment and Economic Growth

Investment on productive infrastructure is important in maintaining good economic performance. Low level of investment on infrastructure is considered as partly responsible for poor growth performance in developing countries (Dissou et al, 2011; Amino, 2008; Foster, 2008). Power infrastructure emerges as the most limiting factor of growth in these countries. So, to stimulate economic growth, investment in infrastructure in the area of energy is important (Heintz et al, 2009).

Barro (1990) model shows the relationship between infrastructure and output. Thus, assuming aggregate output Y, at time *t*, is produced using infrastructure capital, G, other capital, K, labor, L, and total factor productivity, A, the following model shows the relationship between infrastructure and output:

$$Y_t = A_t K_t^{\alpha} G_t^{\beta} L_t^{1-\alpha-\beta} \text{ -- (2.9)}$$

Like capital and labor, infrastructure including energy also affects output production. So, energy can be constraint for production if there is no adequate supply of it.

Economic theory identifies that there are five different ways through which infrastructure can positively contribute for economic growth. These ways are categorized in the supply and demand side.

The first way through which infrastructure affects growth is infrastructure as an input of production. In this approach infrastructure may simply be regarded as a direct input into the production process. Increase in the stock of infrastructure would increase the output of the economy as a whole, directly inducing economic growth. The role of power generation infrastructure provides a concrete example of this channel. It is a necessary input for many production processes and so unreliable power supplies render these processes either more expensive or entirely impossible (Fedderke et al, 2008).

The second way is infrastructure as a complement to other factors of production. In this case infrastructure may be regarded as a complement to other inputs in the production process because improvements in infrastructure may lower the cost of production and raises the productivity of other inputs. For example, the productivity of capital such as machinery or electronic equipment is clearly raised by reliable power supplies (Fedderke et al, 2008).

The third way is infrastructure as a stimulus to factor accumulation. In this case infrastructure is considered as a determinant of many factors of production in a typical economy. Therefore, infrastructure may influence growth indirectly, by boosting the accumulation of other factors of production or by boosting the productivity of these factors of production. For example, it is impossible to improve labor skill if there is no education, health stations and adequate supply of power. So, infrastructure, in the form of schools, roads used to access schools and electricity provided to schools determine labor performance (Fedderke et al, 2008).

The fourth way is infrastructure as a stimulus to aggregate demand. The channels mentioned above are purely supply side channels while this one considers the potential role of the demand side. Large infrastructure projects typically involve significant expenditure during construction and operation. This expenditure increases aggregate demand. In turn boosting demand may affect an economy in different ways (Fedderke et al, 2008).

The fifth way is infrastructure as a tool of industrial policy. Sometimes government spend on infrastructure to guide industrial policy. Government by investing in specific infrastructure projects can guide private-sector investment decisions. Through one or all of the above channels investment on infrastructure has positive role on economic growth (Fedderke et al, 2008).

In general, all the theories explained above except the mainstream theory (that gives a little attention to energy) show the importance of energy as one of the important factors to determine economic growth.

2.2. Empirical Literature

Investment on infrastructure facilitates private investment by lowering production costs and creating new markets. It has also a profound impact on total factor productivity (TFP) and it can lead to new production and profit opportunities that contribute for economic development. Perrault et al (2008) constructed a standard computable general equilibrium (CGE) model to explore the impact of scaling up infrastructure in six African countries. They conducted simulations on baseline non-productive investments, roads, electricity, and telecoms under five funding schemes (reduce in other public expenditure to fund investments on these sectors and their maintenance: increase in the value-added tax, increase in import duties, funding from foreign aid and increase income taxes) to compare the impact of increased spending on infrastructure in Benin, Cameroon, Mali, Senegal, Tanzania, and Uganda. They highlighted the most efficient funding mechanism and explored its effect on different macroeconomic and sectoral variables based on comparative analysis.

For the electricity sector they conducted two scenarios. Electricity investment funded by income tax and electricity investment funded by the value added tax. They compared the income tax funding scenario with the VAT option using equivalent variation. The household impact is almost identical to the VAT option in all countries. But they observed very small differences in Benin, Mali, and Tanzania and Cameroon, where the income tax option is more favourable. The impact on GDP is identical for all countries. The change in wage rate is stronger in all countries except for Senegal, where the effect is only slightly less than in the VAT case. The effect on firms' income is also quite similar, although the situation reverses for Cameroon.

A very important conclusion from all the scenarios is that if the current account needs to be balanced, funding investment through foreign aid produces the strongest sectoral effects, because strong price and nominal exchange rate adjustments are needed to clear the current account balance. Sectoral effects are strongly influenced by the structure of imports and exports in the different countries and by the size of inflow of funds required to finance these infrastructure.

Mbanda et al (2011) analysed the impact of public infrastructure investment in South Africa using dynamic CGE analysis. To assess the impact of public infrastructure, the study introduced different policy scenarios. They used four financing options to finance a 47% increase in public infrastructure investment namely: reallocation of capital from private sector to public sector, financing by 50% government budget deficit, 4% increase in indirect tax on commodities, and an increase in direct tax. The results show that financing public infrastructure investment by direct taxation yields better results in terms of impact on aggregate output production, private investment, job creation, and household income. On the other hand, deficit financing seems to result the worst impacts on the economy in terms of above variables. Increasing public infrastructure investment in general is beneficial for the economy.

In the same way Aminu (2008) used a CGE model of Nigeria to investigate the impact of a substantial and sustained investment in electricity-infrastructure on economic growth and other macroeconomic variables. The study followed two approaches in modelling production: constant and increasing returns to scale assuming increasing returns to scale in the infrastructural sector due to the existence of a few large firms in the sector (particularly true in the case of electricity) and constant returns to scale across the other sectors. The paper found that the existence of increasing returns in the electricity-infrastructure sector impacts positively on other sectors of the economy. The study equally finds that a 200billion Nigerian dollar investment (every year from 2008 to 2013) in the nation's electricity- infrastructure sector results economic growth of 10.58 percent and 6.69 percent when increasing returns to scale in electricity sector and constant returns to scale prevails in all the other sectors in Nigeria.

Galinis et al (2000) used a CGE model to analyse the future of nuclear energy in Lithuania. The results of the paper are based on two scenarios. The first scenario is increases in nuclear capacity to generate additional electricity. In this scenario the export sector, agriculture and bulk goods industry is stimulated. Energy demand remains directed towards nuclear electricity, while economic growth boosts fuel consumption. The second scenario is limiting nuclear power potential. In this case economic growth is relatively low, especially in the trade (commercial and public) sectors, services, and transport. Due to low factor prices, marginal costs are low and exports are stimulated; the trade balance improves. The moderate economic growth limits the increase in energy use and decrease emissions. So, improving supply of energy has positive impact on economic growth in Lithuania.

The benefit from investing on infrastructure may depend on heterogeneity of economic agents. CGE models developed in developing countries are based on adaptive expectation and assume myopic economic agents. Dissou et al (2011) assessed the growth, sectoral and welfare implications of increased spending on infrastructure in Benin, using a multi-sector inter temporal general equilibrium model with public capital and heterogeneous agents (forward looking and myopic). They considered two financing methods of public investment booms: domestic financing through discretionary taxes and foreign financing through increased foreign aid. The results show that increased public investment on infrastructure has positive impacts on private investment for all agents in the long run irrespective of financing method. But, it has no positive impacts in the short run. The investment level of myopic agents is adversely affected in the short run by tax financing methods. It has also a Dutch disease effect in the short run but it increases capacity of firms in the long run. In general, forward looking agents benefit more than myopic agents from public investments.

Strzepek et al (2006) analysed the economic impact of high Aswan dam in Egypt. In their study, they used a CGE model of the Egyptian economy to estimate the impact of the High Aswan Dam. The results of simulations show how Egypt's economy would have performed in 1996/97 without the dam and how the economy, without the dam, would have been affected by year-to-year variations in the Nile flows. Variations in flows affect the economy through the availability of water supplies for agriculture, the generation of hydropower, navigation, and tourism. In all simulations, the "shock" is to reduce the supply of summer water, using historical data on summer water flows. In effect, the removal of the dam is assumed to force Egypt to use less water in the summer season, with an excess supply of water in the winter. The shock is applied to agriculture, transport, tourism, and power generation. According to their result, if the High Aswan Dam were not there, agriculture gains (especially summer crops with high value) and the burden of the shocks falls on the non-agriculture sectors, with declines in power, transportation, and tourism.

Adenikinju (2005) analyses the costs of infrastructure failures in Nigeria due to power outages, to the business sector using the revealed preference approach. The paper shows that the poor state of electricity supply in Nigeria has imposed significant costs on the business sector.

Economic impacts of infrastructure, especially on energy, do not depend only on the nature of agents but also depends on the degree of environment impacts and alternative sources of energy supply. The usage of non-renewable energy sources is associated with large-scale emissions of greenhouse gases: carbon dioxide and methane to the atmosphere. To curb such problems, an economy needs to move towards low carbon energy system or decarbonisation of the world energy sources by giving priority to renewable energy sources. In turn such moves from non-renewable to renewable resources have impact on employment and other macroeconomic variables. Kuster et al (2007) developed a CGE model for evaluating energy policy measures with emphasis on their employment impacts specifying a dual labor market with respect to qualification and a technology detailed description of electricity generation. The model they developed was applied for the analysis of capital subsidies on the application of technologies using renewable energy sources, emission caps and trade to reduce carbon emissions.

According to Kuster et al (2007), subsidies on capital alter technologies' comparative advantages as reflected by costs of power generation and subsidizing technologies for renewable energy sources leads to substitute conventional sources to these sources. The impacts are regionally diverse and depend on the prevailing national electricity generation system and on the existence of emission cap regimes. Quantitative results of subsidies on these technologies using renewable energy sources do not automatically lead to a significant reduction in emissions and increase unemployment for both skilled and unskilled labor because renewable energy sources technologies are less labor intensive than most conventional ones.

Aydin (2010) analysed economic and environmental impact of hydropower construction in the Turkish economy. He used a dynamic multisectoral general equilibrium model for the Turkish economy and analyzed the potential long term impacts of a hydro power expanding shock on some macroeconomic variables such as GDP, real consumption, real investment, exports, imports, trade balance, and carbon emissions under policy scenario of doubling hydro power generation. The results of the study show that such shocks have positive impacts on economic growth without increasing carbon dioxide emission.

Rowlandes et al (2002) investigated the relationship between consumers' perceptions of the environmental impact of different energy sources and willingness to pay for green power (electricity generated by more environmentally friendly means) in Canada. The result of the study shows that large hydropower, nuclear energy and natural gas are not as popular among the most environmentally mobilized section of the consumer market. Most of above studies used partial equilibrium models and/ or static CGE and were unable to consider economy wide impact of energy shocks and dynamics.

Waerras (1998) analysed the economic impacts of renewable energy investment using input output analysis for the southern Mediterranean countries and found that renewable energies have positive impact on employment, imports and value-added of industrial sector..

Another important point in the energy consumption-economic growth relationship is the flow of causality between the two variables. Understanding causality between energy consumption and economic growth is important to develop policies allowing for efficient use and adequate supply of energy. Some studies show that economic growth is a critical determinant of consumption of energy and others show energy consumption is causing factor for economic growth.

Altinay et al (2005) in their study 'electricity consumption and economic growth: evidence from Turkey' used Granger Causality and Vector Autoregressive model to investigate the causal relationship between electricity consumption and real GDP for Turkey and found a strong evidence for unidirectional causality running from electricity consumption to income implying increase in electricity supply causes economic growth.

Aqeel et al (2001) obtained similar results for Pakistan. In their study, using Co-integration and Granger Causality they found that electricity consumption leads to economic growth without feedback effects but economic growth leads to total energy consumption. Ukpong (1976) established the existence of a positive relationship between electricity consumption and economic development for Nigeria.

Mehari (2011) examined the causal relationship between energy and economic growth using multivariate frame work including labor and capital as additional inputs and evaluated the relative importance of energy, capital and labor in Ethiopia. He used the Granger causality test and found that causality running from economic growth to energy consumption. In opposite to Mahari, Yohannes (2010) found causality running from energy consumption to economic growth using autoregressive Distributive Lag Model and Johansen test for co-integration for Ethiopia

The study by Bayraktutan et al (2011) found identical impacts of renewable energy supply in OECD countries using Granger causality tests. According to their causality test, renewable electricity generation affects economic growth positively and economic growth gives opportunity to increase electricity from renewable resources in the OECD countries i.e. there is bidirectional impact between energy consumption and economic growth.

Morimoto et al (2004), using time serious data for the period of 1960-1998 from Sri Lanka, found that change in electricity supply leads important changes in real GDP.

In general, this section reveals that investment on infrastructure has significant impact on economic growth. It has positive impact on household income, job creation, investment and overall aggregate output production. Specially, improving the supply of energy has strong effects on sectoral output, trade balance when financed through increased foreign capital inflow, private investment and overall economic growth. However, the impact of investment on electricity on the above variables in Ethiopia is not analysed by dynamic CGE model.

CHAPTER THREE

OVERVIEW OF ENERGY SECTOR IN ETHIOPIA

3.1. Economic Performance of Ethiopia

Ethiopia is located in the Horn of Africa between 3.5° and 14°N and 33° and 48°E. The country registered a rapid economic growth (average GDP growth rate of 11% per year) from 2005/6 to 2009/10. The agricultural, industrial and service sectors grew by 8.4%, 10% and 14.6%, respectively in the same period. Agriculture has been the dominant sector of the country accounting 41% of GDP; the industrial and service sectors contributed 13% and 46% of GDP in 2009/10 respectively (MoFED, 2010). Around 12 million households, that comprise some 85% of the total population depends for its livelihood on agricultural activities.

The country has planned an average GDP growth rate of 14.9% for the coming four years under the high case scenario. To this end the government developed its Growth and Transformation Plan (GTP) in 2011 that gives emphasis to the growth of industrial sector and aims at achieving growth rate of 21.3% for the sector. In doing so, it aims at making the industrial sector play a leading role in the economy. In the plan the agricultural sector will grow at 14.9%, and the service sector will grow at 12.8% (MoFED, 2010).

To promote industry and make it leading sector, one observes the need for improvement of country's infrastructure. Infrastructure constraints are responsible for an estimated 50% of the productivity constraint faced by Ethiopian firms (Eberhand et al, 2011, Foster et al, 2010). The country's greatest challenge in infrastructure lies in the power sector. Power is by far the largest constraint that weighs most heavily on Ethiopian firms (Foster et al, 2010).

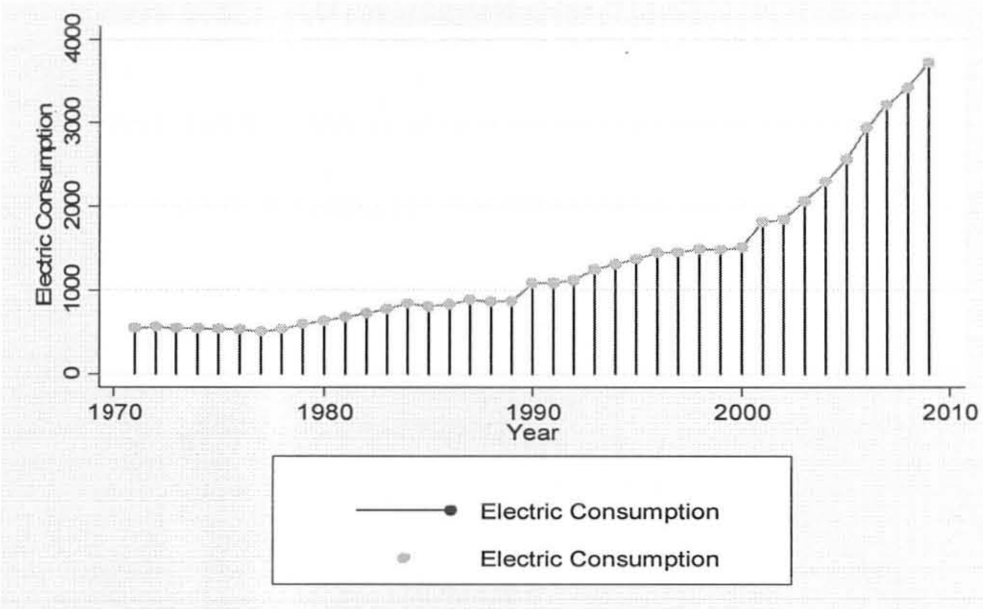
3.2. Energy Consumption in Ethiopia

Compared to most countries in the world, Ethiopia's energy consumption per capita is extremely low. Even though the country has a large share of water and other energy sources in its energy mix, 87.9% of Ethiopia's final energy consumption comes from biomass (wood, charcoal and agricultural residues). The main use of biomass is concentrated in cooking in both the residential and commercial sectors. A major problem of biomass use in the country is the fact that it is utilized inefficiently and results in deforestation and outdoor and indoor pollution (Heimann, 2007 and Lakew et al, 2011).

Electricity provides only 2.6% of total energy consumption in the country. It has 12,150 Km of transmission and 126,000 Km of distribution lines throughout the country. Electricity consumption stagnated during the period between1972 to 1980. The reason for this stagnation was largely attributed to the Derg Regime's policies which discourage the private sector and it might also be due low electricity production. Consumption of electricity started to pick up slightly from 1980 to 2000. It increased dramatically in the last decade after 2000 which would be due to rapid economic growth. It reached just over 3,000 GWH after 2008 (Figure 3.1) (WDI, 2010) and is expected to increase in the future. Electricity consumption among household, industrial and commercial sectors is 38%, 36 % and 26% respectively (MoWE, 2012).

Though there is rapid increase in electricity consumption, the per capita consumption of Ethiopia is extremely low compared to low income countries. The average per capita power consumption of low income countries is 99.5 KWh; however, it is only 33.6 KWh for Ethiopia. Petroleum and solid energy fossil fuels comprise 9.2% and 0.2% of final energy supply respectively.

Figure 3.1: Electricity consumption trend in Ethiopia from 1971 to 2009 (GWH)



Source: WDI, 2010

3.3. Organizational Setup of Electricity Sector

The Ethiopian Electric Power Corporation (EEPCo) is the responsible government owned organization for supplying the utility in Ethiopia. It was named in 1997- after serving previously under the name of the Ethiopian Electric Light and Power Authority, which was established in 1956 to change it to commercially oriented corporation by Regulation no. 86/1997 under the Public Enterprises Proclamation No. 25/1992. It manages the generation, transmission, distribution and sale of electric power to consumers throughout the country. It is the major supplier of electricity. The organization has two electric power supply systems: the Interconnected System (ICS) and the Self Contained System (SCS). More than 95% of the power uses the ICS. The main energy source of ICS is hydropower plants consisting 11 hydro, 1 geothermal and 15 diesel power plants with a total capacity of 2022.2 MW, of which more than 90% is generated from hydropower plants. The power supply of SCS uses mini-hydro and diesel power generators consist of three small hydro plants and many isolated diesel plants located throughout the country with a capacity of generating 6.15MW and 30.06 MW respectively. Their generation capability from 2005/06 to 2009/10 is depicted in the Table 3.1.

Table 3.1: ICS and SCS sources and share of power (GWH)

Source		2005/06	2006/07	2007/08	2008/09	2009/10
ICS	Hydro	2838.7	3259.8	3368.7	3277.1	3418.6
	Thermal	6.3	9.7	131.8	380.4	418.2
	Geothermal	-	-	-	6.6	23.5
ICS total		2845.0	3269.5	3500.6	3664.1	3860.3
ICS share in %		98.2	98.8	99.2	99	98.8
SCS	Hydro	12.4	5.2	2.7	7.9	20.1
	Thermal	39.2	35.7	27.1	30.5	25.0
	Geothermal	-	-	-	-	-
SCS total		51.5	40.9	29.8	38.5	45.1
SCS share in %		1.8	1.2	0.8	1	1.2
Grand total		2896.5	3310.4	3530.3	3702.6	3905.4

Source: National Bank of Ethiopia, 2009/10 annual report

3.4. Indigenous Sources of Energy in Ethiopia

In Ethiopia, energy supplies are mainly from renewable sources. The country has abundant indigenous energy sources; such as, hydro, wind, geothermal, solar and bio-energy.

3.4.1. Hydropower

Hydropower is the most economically viable source of modern energy in Ethiopia. The exploitable potential of hydropower is 45GW. But only 5% of it has been exploited. There are nine suitable river basins to generate electricity. From these river basins, Abay and Omo-Gibe accounts 72% of total hydropower potential[1]. Next to Abay and Omo-Gibe basin, Baro-Akobo and Genale-Dawa is a major contributor.

In Ethiopia hydropower development for energy was started with mini to small power plants. However, current and planned development is almost exclusively to construct large plants. Hydro power contributes more than 90% of total electricity supply (Table 3.1). After Gilgel Gibe III is completed, it will push the share of hydropower from the total energy supply to 96%. This indicates that dominant energy source for electricity in Ethiopia is hydro (National Bank of Ethiopia, 2009/10).

3.4.2. Wind Energy

"When there is no hydro there is wind, when there is no wind there is hydro. A good match! " This statement of a GIZ energy researcher cited by Heimann (2007) about the climate conditions in Ethiopia suggests that wind energy can provide an important contribution to a sustainable energy supply. The total wind power to generate energy potential in Ethiopia is estimated to be 10,000 MW. There are fifteen good locations to exploit wind power in the county. The first rough measurements to identify these locations were taken as long ago in 1970s and 1980s by the NMA. They are mainly found in the eastern and north part of the country. However, until today wind power does not have a mentionable share in Ethiopia's energy mix. Two wind farms (Ashigoda and Adama) are now started operation in the north and central parts of Ethiopia, with combined power generating capacity of about 170MW. Six additional wind farms are planned to be developed with total capacity of 722MW (Table 3.2).

[1] Based on WAPCo (India) estimates

3.4.3. Geothermal Energy

Ethiopia is endowed with huge geothermal energy resources. It has an estimated generating capacity of 5000 MW. Ethiopian rift valley is rich of a huge geothermal energy. All geothermal energy sites are found in rift valley areas due to the existence of volcanic and hydrothermal activities (Birhanu, 2008, Hilawe et al, 2011 and Holm et al, 2010). These sites are Abaya, Corbetti, Aluto-Langano, Tulu Moye, Gedemsa, Boseti Guda, Boseti Bericha, Kone, Fentale and Dofan in the MER; Meteka, Amoisa, Ayelu, Teo and Danab, Tendaho, Lake Abhe and Dallol areas. However, only one small geothermal plant (7MW) was developed in the mid-1990s. But it has ceased production after a few years it started generation.

Based on their anticipated potential and strategic location with respect to proximity to the national grid, Aluto-Langano, Tendaho, Corbetti, Abaya, Tulumoye-Gedemsa, Dofan and Fantale have been subjected for better exploration schemes.

Generating electricity from geothermal sources, compared to wind and solar energy, is cost effective (cheaper). Despite this potential, the country has not yet benefited from this indigenous and environmentally friendly resource in a meaningful manner. This is fundamentally due to the lack of a sufficient budget to explore and develop in an aggressive and sustainable manner (Birhanu, 2008)

3.4.4. Solar Energy

The current total installed capacity of photovoltaic power in Ethiopia is about 3.5MW. It is mainly used in off-grid rural applications in homes, rural telecoms and in the social sectors (water pumping, health services, schools) (Hilawe et al, 2011). Three-quarters of this capacity is installed in telecom stations (mostly in mobile towers). The following table shows indigenous alternative energy sources in Ethiopia.

Table 3.2: Indigenous energy resources in Ethiopia

Source	Unit	Gross potential	Economic potential	Energy (GWH/year)	Exploited (%)
Hydropower	MW	184,000	45,000	208,926	5
solar	MWe/KM^2	100	100	175	0.1
wind	MW	169,000	10,000	22776	5
Geothermal	MW	5000	1000	6920	1.2
Coal	MW	NA	100	596	0
Natural Gas	MW	NA	600	4468	0

Source: Ministry of Water and Energy, 2010

3.5. Investment on Energy in Ethiopia

From huge energy sources shown in table 3.2, the country had utilized less than 1 GW up to 2009 that was unable to satisfy domestic energy demand and lead to power outages from 2007/08 to 2009/10. In order to solve this problem, the Ethiopian government has strived to exploit the huge electricity generation potential of the country. As a result, large hydro power plants were built in the country. Among these dams, Gilgil Gibe II, Tana Beles and Tekeze projects were commissioned in 2009 and 2010 with combined capacity of 1180 MW. Gilgel Gibe II, which does not have its own dam, has an installed capacity of 420 MW, Tana Beles has 460 MW, and Tekeze I has 300 MW. Consequently, total electricity generating capacity of the country was raised to 2044 MW in 2010.

The large share almost more than 90% of the investment so far was on hydropower. An exclusive reliance on hydropower may be risky and unreliable in times of drought. In addition to hydro new sources of energy are urgently needed. So, Ethiopia must diversify energy sources by investing on alternative energy sources such as wind, geothermal and solar energy.

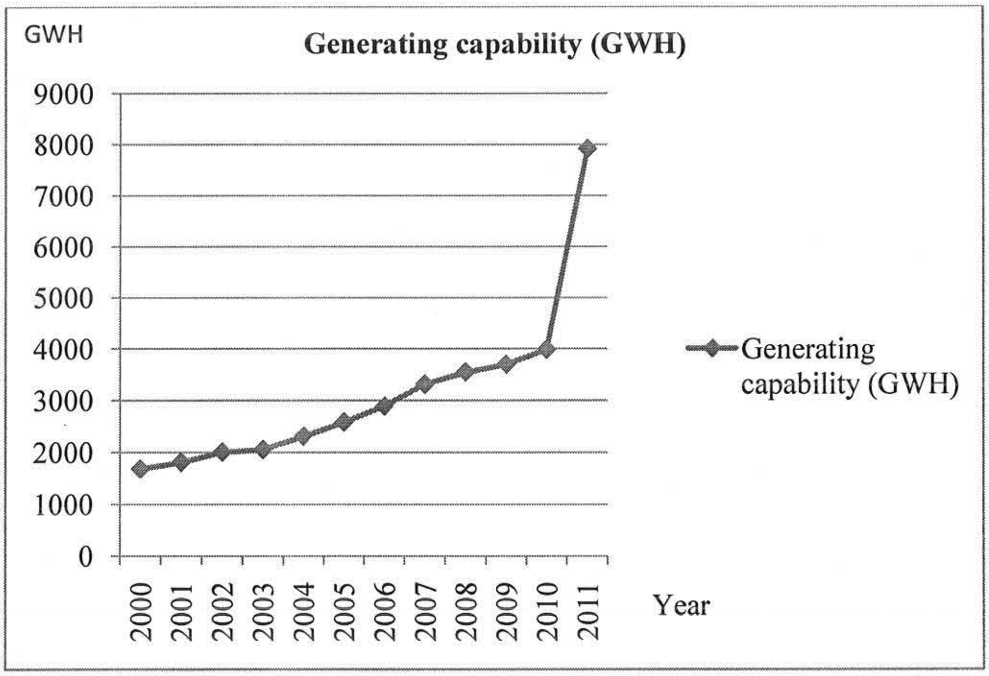
Table 3.3: Power generating capacity of Ethiopia from 2000 to 2011(MW)

	Generation capacity (MW)		
year	Total	Hydro	Non Hydro
2000	420.9	377.8	43.1
2001	494.0	450.8	43.2
2002	491.6	450.8	40.8
2003	526.4	484.8	41.6
2004	801.2	668.8	132.4
2005	814.6	668.8	145.8
2006	819.3	668.8	150.5
2007	816.9	668.8	148.1
2008	816.9	668.8	148.1
2009	876.9	668.8	208.1
2010	2044.1	1848.8	195.3
2011	2142.8	1848.8	294

Source: EEPCo, 2011

Having stagnated between 2002 and 2005, actual electricity production was also considerably increased in between 2006 and 2011 due to aggressive investment in the sector. It reached 7923GWH in 2011 from its level of merely 2000 GWH in 2002 (Figure 3.2). From this total generating capability, 4319GWH was generated from newly inaugurated plants (Beles, Gilgil Gibe II and Tekeze) in 2009 and 2010 and 3604GWH was from the old dams and diesel generators.

Figure 3.2: Actual electricity production in Ethiopia from 2000 to 2010 (GWH)



Source: from EEA data base, 2010

To achieve 7923GWH actual electricity production and to distribute it different parts of the country, 51 billion birr was spent in the last decade. From this spending, more than 43 billion birr was spent in the last five years (2005- 2010). The spending was allocated to generation, transmission, and distribution projects and for other activities such as rural electrification, projects study and institutional strength. 60% of this spending was for generation projects and remain 40% was for transmission, distribution projects and for other activities (Table 3.4).

Table 3.4: Distribution of spending in electricity sector in billion birr (2001-2010)

Year	Generation	Transmission	Distribution	Others	Total
2001	0.37	0.29	0.20	0.75	1.61
2002	0.80	0.30	0.28	0.44	1.82
2003	1.30	0.30	0.30	0.49	2.39
2004	0.70	0.10	0.17	0.76	1.73
2005	1.20	0.50	0.23	0.94	2.87
2006	2.60	0.60	0.87	1.50	5.57
2007	4.10	0.70	0.37	1.78	6.95
2008	5.60	0.60	0.12	0.60	6.92
2009	5.00	2.10	0.29	1.92	9.31
2010	7.70	1.90	0.17	2.07	11.84

Sources: EEPCo, 2011

From the total spending depicted in the Table 3.4 more than 80% was made on fixed assets such as construction materials, machineries, vehicles and other equipments. The value of fixed asset created from investment from 2006/07 to 2009/10 is shown in table 3.5. From 2006/07 to 2009/10 total of 30.88 billion birr net capital stock was created from the total investment of 38.73 billion birr. To get net capital stock for each year new investment is added to the book value at the beginning of the year, then the depreciation, sold and disposed values are deducted from gross capital formation at the end of the year.

Therefore, investment on electricity infrastructure has a significant impact on capital accumulation of the sector. Whenever there is investment on electricity sector, the demand for machineries, equipments, vehicles and other construction materials increases which in turn increase capital asset of the sector.

Table 3.5: The value of capital asset created from investment on electricity (in billion birr from 2006/07-2009/10)

	2006/07	2007/08	2008/09	2009/10
Building	0.019	0.018	0.016	0.016
Construction & works	6.40	6.30	11.70	5.60
Machinery &equipments	4.00	4.70	0.20	5.40
Vehicles	0.04	0.09	0.10	0.10
Construction in process	9.10	17.9	32.5	35.1
Others	0.007	0.007	0.007	0.006
total value of capital stock	19.80	29.00	44.5	46.3

Source: National Bank of Ethiopia, 2010

3.6. Planned Investment on Electricity

Though there is huge investment in power sector from 2008 to 2010, there is still power shortage in the country which will be due to the expansion of electric coverage in the country and increasing need from the growing industry and service sectors creating unprecedented electricity demand that exceeded the available electricity generation capacity (MoWE, 2012). To solve these chronic power outages and export to neighbouring countries, the Ethiopian government is implementing ambitious investment on electricity infrastructure. From these planned investment projects the country is expected to generate 13230 MW power in 2016 when all projects are commissioned (Table 3.6).

Table 3.6: Expected Power generation capacity (MW) and generation capability (GWH) (2011-2016)

year	Generation Capacity	Generation capability
2011	2142.8	7923
2012	2690.8	10576
2013	4857.8	12140
2014	5111.8	19234
2015	8053.8	32656
2016	13303.8	NA

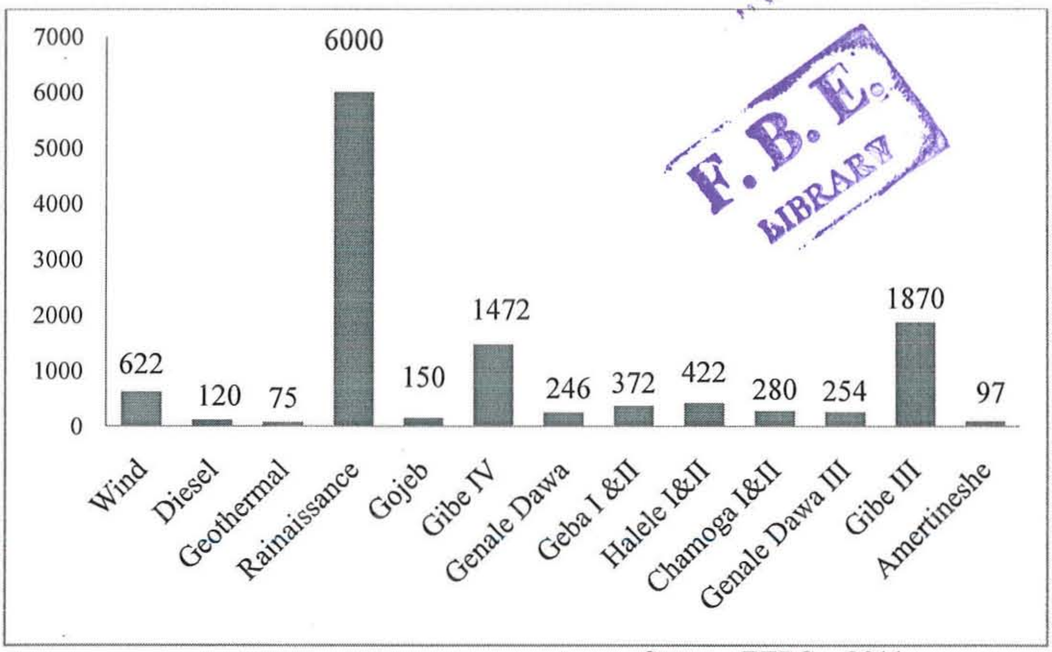
Source: EEPCo, 2011

After all projects are commissioned, electricity generation capacity of the country will be six times of current generating capacity. As a result actual energy production of the country will be 32656GWH at the end of 2015 from merely 7923GWH in 2011. Among the planned projects, three large dams (Renaissance Dam, Gibe III and IV Dams) comprise more than 65% of total power generation.

Almost half of the total generation capacity will be from Renaissance dam which is expected to generate 6000 MW and will be completed in 2016. The dam will have 15 units each with a 350 MW capacity, On the other hand, the total electricity production from this dam is expected to be 15,128 GWH on annual basis. Next to Renaissance dam, Gibe III and IV are expected to generate more than 3000MW power (Figure 3.3).

In the planned investments there are also wind and geothermal projects which are expected to generate 622 MW and 75 MW after completion respectively (Figure 3.3). This shows that there is diversification of energy sources in the planned investment which will help reduce risk and uncertainty in the time of drought.

Figure3.3: Planned investment projects and their generating capacity in MW



Source: EEPCo, 2011

The main challenges of this ambitious electricity investment are financing sources. The country's power infrastructure needs are massive and would require approximately 41 billion birr per year from 2011 to 2015. The total planned budget for these years is 207 billion birr. This budget does not include Aluto Langano geothermal and MDS1 projects (Appendix A). 62% of the budget is planned to finance capital expenditure and 38% of it is to finance operation and maintenance costs and administrative salaries (will be financed by EEPCo's internal financing sources).

From the projects, Renaissance Dam will require 79 billion birr and expected to be financed domestically through domestic grants and bond selling since there are no financing sources from abroad. Almost all other projects are going to be financed through foreign loans.

Table 3.7: Planned budget to finance electricity infrastructure (2011-2015)

							Total
	EC	2003	2004	2005	2006	2007	2003-2007
	GC	2011	2012	2013	2014	2015	2011- 2015
Generation		22.21	35.24	40.73	31.55	22.64	152.36
Transmission		5.94	13.59	10.19	7.06	6.63	43.41
Distribution		0.2	0.22	0.24	0.27	0.29	1.22
Institutional Strengthening		0.07	0.006	0	0	0	0.076
Study		0.004	0.005	0	0	0	0.009
UEAP		3.81	2.56	2.69	0.81	0.81	10.68
		32.23	51.67	53.84	39.69	30.37	207.79

Source: EEPCo, 2011

CHAPTER FOUR

DATA AND METHODOLOGY

4.1. The Social Accounting Matrix

The standard CGE model explains all of the payments recorded in the SAM. The model follows the SAM disaggregation of activities, commodities, factors and institutions (Lofgren et al, 2002). This study used an updated version of 2005/06 SAM which represents the Ethiopia economy by activities, factors (capital, land and different types of labor) and commodities and institutions (households, government and the Rest of World), including an aggregate savings-investment account (EDRI, 2009).The following part explains SAM in detail.

A social accounting matrix (SAM) is a comprehensive, economy wide data framework, typically representing the economy of a nation. The 2005/2006 Ethiopia SAM is the first comprehensive economy wide dataset. A SAM can be seen as an extension of input-output (I-O) matrices, filling in the links in the circular flow from factor payments to household income and back to demand for products[2] .The SAM delineates flows across product and factor markets, and provides the statistical underpinnings for multi-sector, multi-factor, computable general equilibrium (CGE) models, as the national accounts provide the data framework for macro-econometric models (EDRI, 2009).

More technically, a SAM is a square matrix in which each account is represented by a row and a column. Each cell shows the payment from the account of its column to the

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[2]The Input-Out table shows the interdependence among various producing and demanding sectors of the economy as they interact as each other's customers. It provides a systematic description of each sector's interdependence by tracing the flows of goods and services from one sector of the economy to all other sectors (inter-sectoral flows) and to itself (intra-sectoral flows) (EDRI, 2009).

account of its row. Thus, the incomes of an account appear along its row and its expenditures along its column. The underlying principle of double-entry accounting requires that, for each account in the SAM, total revenue (row total) equals total expenditure (column total) (Lofgren et.al, 2002).

With regard to the structure of the standard SAM, it has a number of accounts such as activities, commodities, institutions, factors of production and saving-investment accounts. In addition to these accounts varies SAM may have extra accounts like taxes, total margins.

The standard SAM distinguishes between accounts for activities (the entities that carry out production) and commodities. The commodities are activity outputs, either exported or sold domestically, and imports. This separation of activities from commodities is preferred because it permits activities to produce multiple commodities while any commodity may be produced by multiple activities (Lofgren et.al, 2002).

The activity accounts show the value of commodities (goods and services) produced by each activity and the cost of inputs into each production activity consisting of intermediate input purchases along with payments to primary factors of production. Commodity accounts show the components of total supply in value terms (domestic production, imports, indirect taxes and marketing margins) and total demand (intermediate input use, final consumption, investment demand, government consumption and exports). Factor accounts describe the sources of factor income and how these factor payments are further distributed to the various institutions in the economy (EDRI, 2009).

In the commodity columns, payments are made to domestic activities, the rest of the world, and various tax accounts (for domestic and import taxes). The matrix explicitly associates trade flows with transactions (trade and transportation) costs, also referred to as marketing margins. For each commodity, the SAM accounts for the costs associated with domestic, import, and export marketing. For domestic marketing of domestic output, the marketing margin represents the cost of moving the commodity from the producer to the domestic demander. For imports, it represents the cost of moving the commodity from the border to the domestic demander, while for exports it shows the cost of moving the commodity from the producer to the border.

The institution account summarizes payments among government, households, enterprises, and rest of the world. In the SAM, payments between the government and other domestic institutions are reserved for transfers. In the matrix for government – household sub account the row represents the income to government from taxes (direct and indirect taxes), direct transfer from households and the rest of the world. The enterprises earn factor incomes (reflecting their ownership of capital and/or land). They may also receive transfers from other institutions (the rest of the world and government).The rest of the world makes payments for exports, factors, transfers to households and government, and foreign saving. Technically, the standard CGE model requires that the SAM have at least one household account; however, enterprise accounts are not necessary (Lofgren et.al, 2002).

The factors of production account reports payments to factors from activities in the domestic economy and the rest of the world and distribution of their income to different institutions on the row and column. The factors of production in the SAM consist of four types of labor: Skilled, Semi skilled, unskilled workers and agricultural labor. In addition, it consists of land, livestock and capital

The savings-investment (S-I) account should be seen as representing the "loanable funds" market. The account collects savings from various sources (government, private, and foreign) and spends the accumulated savings on capital goods (I). The SAM provides no information about who "owns" the capital goods or in which sectors they are installed. Investment demand in the SAM is by sector of origin, not sector of destination, so the SAM cannot provide information about changes in sectoral capital stocks, or their valuation (EDRI, 2009).

The SAM incorporates the three macro balances: government deficit, trade deficit, and savings-investment balance. The macro balances are expressed as flows. The SAM does not include asset account. Therefore, any macro relationship in this framework will be in flow terms (EDRI, 2009). Also in the standard SAM payments are not permitted in the blank (empty) cells.

As the current structure of the Ethiopian economy is different from 2005/06 on which the existing SAM is based, it was updated in 2009. This study is used the updated version of 2005/06 SAM. The updated 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 including 12 households. The SAM also has different taxes, saving-investment, inventory, and rest of the world accounts to 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).

4.2. Foundations for CGE Model: The Circular Flow and Walrasian Equilibrium

The basic foundation for CGE framework is the circular flow and Walrasian Equilibrium condition. The fundamental conceptual starting point for a CGE model bases on the circular flow of commodities in a closed economy, shown in Figure 4.1. The circular flow diagram has two markets: product and factor markets (Wing, 2004). The main actors in circular flow diagram are households, who own the factors of production and are the final consumers of produced commodities, and firms, who rent the factors of production from the households for the purpose of producing goods and services that households then consume. They interact among themselves in product and factor market (Wing, 2004).

In factor market households are sellers (suppliers) of factors of production while firms are buyers (demanders) of factors of production. In product market firms are sellers (suppliers) of goods and services while households are buyers (demanders) of goods and services. In tracing the circular flow we can start with the supply of factor inputs (e.g. labor and capital services) to the firms and continue to the supply of goods and services from the firms to the households, who in turn control the supply of factor services or begin with payments, which households receive for the services of labor and capital provided to firms by their primary factor endowment, and which are then used as income to pay producing sectors for the goods and services that the households consume (Wing, 2004).

Equilibrium in the economic flows in Figure 4.1 results in the conservation of both product and value. Conservation of product, which holds even when the economy is not in equilibrium, reflects the physical principle of material balance that the quantity of a factor with which households are endowed, or of a commodity that is produced by firms, must be completely absorbed by the firms or households in the rest of the economy. Thus, for a given commodity, the quantity produced must equal the sum of the quantities of commodity demanded by the other firms and households in the economy. This is the familiar condition of market clearance.

Conservation of value reflects the accounting principle of budgetary balance that for each activity in the economy the value of expenditures must be balanced by the value of incomes, and that each unit of expenditure has to purchase some amount of some type of commodity. The implication is that neither product nor value can appear out of nowhere: each activity's production or endowment must be matched by others' uses, and each activity's income must be balanced by others' expenditures.

The accounting principles are the cornerstones of Walrasian general equilibrium. Walrasian equilibrium typically defines price and commodity vectors such that there is no good for which there is positive excess demand (Varian, 1992). Walrasian general equilibrium prevails when the price of commodities equal to their marginal cost of production with firms earning zero profits, there is no excess demand for commodities and factors, and consumers' income equals their expenditure (Wing et al, 2007).

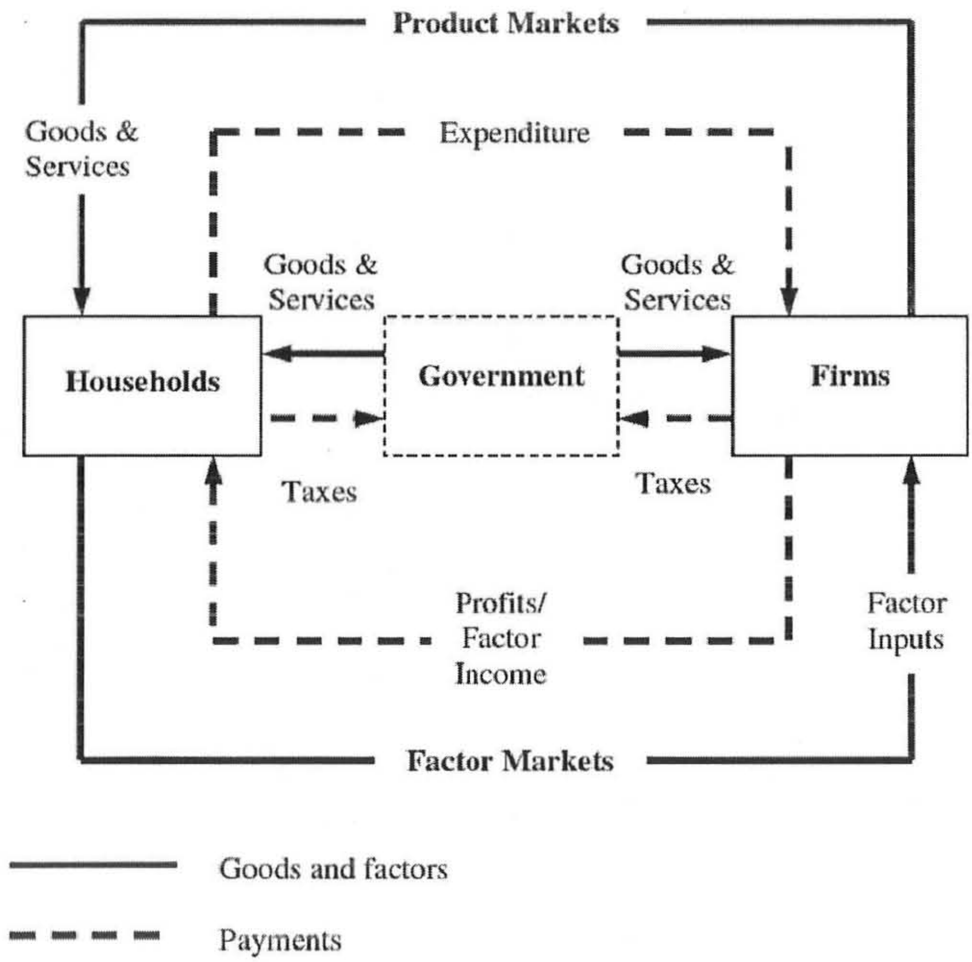
Conservation of product, by ensuring that the flows of goods and factors must be absorbed by the production and consumption activities in the economy, is an expression of the principle of no free disposability. This is the familiar condition of market clearance

Conservation of value implies that the sum of total revenue from the production of goods must be allocated either to households as receipts for primary factors rentals, to other industries as payments for intermediate inputs, or to the government as taxes. The value of a unit of each commodity in the economy must then equal the sum of the values of all the inputs used to produce. These conditions imply that at equilibrium producers make zero profit in perfectly competitive market (Wing, 2004).

Lastly, the returns to households' endowments of primary factors that are associated with the value of factor rentals to producers accrue to households as income that the households exhaust on goods purchases. They exhaust their income on commodity purchases (some amount of which are for the purpose of saving), reflects the principle of balanced-budget accounting known as income balance.

So, market clearance, zero profit and income balance conditions explained above are employed by CGE models to solve simultaneously for the set of prices and the allocation of goods and factors that support general equilibrium. These conditions define Walrasian general equilibrium not by the process of exchange by which this allocation comes about, but in terms of the allocation itself, which is made up of the components of the circular flow shown by solid lines (Wing, 2004).

Figure 4.1: Circular flow of the economy



(Source: Wing, 2004)

4.3. Overview of Standard Computable General Equilibrium Model

The CGE framework is close simulation of the real economy because it captures the net effect of changes in resource allocation by allowing the best selection amongst input and output choices available in different markets. CGE model includes flexibility in specifying technology and consumer preferences, use of prices to drive the changes in allocation, and an almost free choice of the level of sectoral disaggregation. CGE models also allow us to specify the nature of substitution between factor inputs on the supply side, and between imports and domestic supply on the demand side by choosing appropriate functional forms (Guha, undated).

CGE models offer an economy-wide assessment of policies, including the concurrent effects of policy-changes (Thurlow, 2004). Compared to partial equilibrium models, CGE models have more theoretical base (Kremers, 2008) and its framework is a reasonably close simulation of the real economy. It includes substitution effects and interaction among different markets. Partly for these reasons, CGE modelling is regarded as a powerful, flexible and useful analytical and simulation device for distinguishing between the multiple effects across economies that might be triggered by various policy shocks (FAO, 2003).

In order to analyze the economy wide impact of investment on infrastructure for electricity in Ethiopia a Recursive Dynamic Computable General Equilibrium model is used because this model is based on adaptive expectation which is more relevant for developing countries. It is also best suited to assess the long run energy infrastructure investment impact as dynamic CGE Models are important tools for economic policy (Paltsev, 2004).

The model explains all of the payments recorded in the SAM of Ethiopian economy. It follows the SAM disaggregation of factors, activities, commodities, and institutions. It is written as a set of simultaneous equations, many of which are nonlinear. The equations define the behaviour of the different actors. There is no objective function (Lofgren et.al, 2002). In part, this behaviour follows simple rules captured by fixed coefficients (for example, ad valorem tax rates).

For production and consumption decisions, behaviour is captured by nonlinear, first-order optimality conditions that are driven by the maximization of profits and utility respectively. The equations also include a set of constraints that have to be satisfied by the system as a whole but are not necessarily considered by any individual actor. 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) (Lofgren et.al, 2002). The CGE models also include equations for closures. Solving the CGE model entails the specification of closure conditions that refer to the balancing of major accounts in the economy demand, supply, government and external sectors.

CGE models typically do not explicitly represent money as a commodity. However, in order to account for such trades the quantities of different commodities still need to be made comparable by denominating their values in some common unit of account. The flows are thus expressed in terms of the value of one commodity the so called numeraire good whose price is taken as fixed. For this reason, CGE models only solve for relative prices (wing, 2004).

CGE models are broadly divided into two: static and dynamic. Static CGE models show one time effects of policy changes while dynamic CGE considers the second round effect. Even though static CGE are simple for application, they are unable to account for growth or second effects (Annabi et al, 2004). Most CGE models are static in nature because consumers' demands are derived from a one-period utility function. Household savings is not endogenously determined using an inter-temporal utility function, and so it does not smooth consumption over time. Dynamic CGE is developed to solve these problems.

Dynamic CGE model is divided into two: truly dynamic (intertemporal) and recursive dynamic (sequential).Truly dynamic model is based on optimal growth theory where the behaviour of economic agents is characterized by perfect foresight. They know all about the future and react to price change in the future. Recursive dynamic model is basically a series of static CGE models that are linked between periods by an exogenous and endogenous variables updating procedure. Capital stock is updated endogenously with a capital accumulation equation and labor supply is updated exogenously between periods and made endogenous (Annabi et al, 2004)[3].

Therefore, since capital accumulation cannot be defined inter-temporally, the dynamics in our CGE model is defined as a recursive process; this means that we can separate the model into "within-period or one period static" and "between-period or dynamic" components (Thurlow, 2004). The equations presented below fully specify the within-period component, in which consumers and producer maximize their utility and profits based on prevailing factor and product prices (i.e. without forward-looking expectations). Then, in between-periods, certain exogenous variables are updated based on previous period results (e.g. capital accumulation) (Diao et al, 2011).

4.3.1. One Period Static CGE Blocks

Price Block

The price system of the CGE model is rich primarily because of the assumed quality differences among commodities of different origins and destinations (exports, imports and domestic outputs used domestically). The price block consists of equations in

[3] Cockburn et al (2006) showed that it is impractical to assume perfect foresight particularly for developing countries. Consequently, in most of empirical studies sequential dynamic model is adopted. Thus, for Ethiopia it is appropriate to adopt a recursive dynamic model.

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which endogenous model prices are linked to other prices (endogenous or exogenous) and to non price model variables[4].

Import Price

The import price (PM_C) in local-currency units (LCU) is the price paid by domestic users for imported commodities (exclusive of the sales tax). Domestic import price of commodity c is the product of world import price of c (PWM_C), the tariff adjustment ($1+tm_c$) and exchange rate (EXR) plus transaction costs to move the commodity from the border to the domestic demander.

$$PM_C = pwm_c.(1+tm_c).EXR + \sum_{c' \in CT} PQ_{c'}.icm_{c'c} \qquad c \in CM \text{ -------- } (4.1)$$

Where, PQ_c is composite commodity price (inclusive of sales tax and transaction costs), $icm_{c'c}$ is trade input per imported commodity, CT is a set of domestic trade inputs, CM is a set of imported commodities.

The exchange rate is in terms of local currency per unit of foreign currency. The exchange rate and the domestic import price are flexible, while the tariff rate and the world import price are fixed[5].

Export price

The export price in LCU is the price received by domestic producers when they sell their output in export markets. The domain of the equation is the set of exported commodities, all of which are produced domestically.

Mathematically,

$$PE_c = pwe_c.EXR - \sum_{c' \in CT} PQ_{c'}.ice_{c'c} \text{ --- } 4.2$$

---

[4] All the equations for within model are taken from Lofgren et.al, 2002

[5] The fixedness of the world import price stems from the small country assumption. This is to mean, for the modelled country, the assumed share of world trade is so small for all of its import. Consequently, the country faces an infinitely elastic supply curve at the prevailing world price (Lofgren et al., 2002).

Where, c $\in$CE ($\subset$ C) is a set of exported commodities (with domestic production), PE_c is export price (LCU), pwe_c is f.o.b. export price (FCU), $ice_{c.c}$ is quantity of commodity c as trade input per exported unit of c[6].

Consumer Price and Producer Price Index

Equations (4.3) and (4.4) define the consumer price index and the producer price index. The CPI is fixed and functions as the numeraire in the basic model version; alternatively, the DPI may be fixed.[7]

$$\overline{CPI} = \sum_{c \in C} PQ_C \cdot cwts_c \text{ ------------ } 4.3$$

$$DPI = \sum_{c \in C} PDS_C . dwts_c \text{ ------------ } 4.4$$

Where, $cwts_c$ is weight of commodity c in the consumer price index, CPI is consumer price index (exogenous variable), $dwts_c$ is weight of commodity c in the producer price index, and DPI is producer price index for domestically marketed output.

Demand Price of Domestic Non-trade Goods

The model includes distinct prices for domestic output that is used domestically. In the presence of transaction costs, it is necessary to distinguish between prices paid by demanders and those received by suppliers. The following equation defines the domestic demand prices (PDD_c) as the domestic supply price (PDS_C) plus the cost of trade inputs per unit of domestic sales of the commodity.

$$PDD_C = PDS_C + \sum_{c' \in CT} PQ_C . icd_{c'c} \qquad c \in CT \text{ ------------ } (4.5)$$

---

[6] In Ethiopia there is no imposition of tax on export. Thus, te_c (export tax rate) is removed from export price equation because it is zero for the case of Ethiopia).

[7] A numeraire is required since the model is homogeneous of degree zero in prices i.e. a doubling of the value of the numeraire would double all prices but leave all real quantities unchanged. All simulated price and income changes should be interpreted as changes vis-a-vis the numeraire price index.

Where, $c \in CD (\subset C)$ is a set of commodities with domestic sales of domestic output, icd_c and c is quantity of commodity c as trade input per unit of c produced and sold domestically.

Aggregate Intermediate input price

The activity-specific aggregate intermediate input price shows the cost of disaggregated intermediate inputs per unit of aggregate intermediate input. It depends on composite commodity prices and intermediate input coefficients which show the quantity of input commodity c per unit of aggregate intermediate input (not per unit of output).

$$PINTA_a = \sum_{c \in C} PQ_c . ica_{ca} \text{ --- } (4.6)$$

Where, $PINTA_a$ is aggregate intermediate input price for activity a and ica_{ca} is quantity of *c* per unit of aggregate intermediate input *a*.

In this block, in addition to the above different price equations, marketed output value, activity price, and activity revenue and costs equations are specified.[8]

Production and Trade block

The production and trade block covers four categories: domestic production and input use, the allocation of domestic output, the aggregation of supply to the domestic market and the definition of the demand for trade inputs that is generated by the distribution process.[9]

[8] For each domestically produced commodities the marketed output value at producer prices is stated as the value of domestic sales and exports, activity price represented as multiplication of yields per activity unit by activity-specific commodity prices summed over all commodities, and activity revenue and cost equations state for each activity, total revenue net of taxes is fully exhausted by payments for value-added and intermediate inputs (Lofgren et al, 2002).

[9] Domestic output is allocated to home consumption, the domestic market and exports. Aggregate supply to domestic market is the sum of import and domestic output sold domestically.

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Production is carried out by activities that are assumed to maximize profits subject to their technology, taking prices (for their outputs, intermediate inputs, and factors) as given. Five factors of production are specified in the model: unskilled labor, skilled labor, semiskilled labor, capital and land.

Each producer (represented by an activity) is assumed to maximize profits, defined as the difference between revenue earned and the cost of factors and intermediate inputs. Profits are maximized subject to a production technology. At the top level, the technology is specified by a constant elasticity of substitution (CES) function or, alternatively, a Leontief function of the quantities of value-added and aggregate intermediate input (Lofgren et al, 2002). CES allows producers to respond to changes in relative factor returns by smoothly substituting between available factors so as to derive a final value-added composite. Value added is itself a CES function of primary factors which makes producers responds to dynamics in factor returns by substituting among available factors (Thurlow, 2004).

Once factors receive income at profit maximization condition they combine with fixed share intermediates using Leontief specification. The use of 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(Lofgren et al, 2002). In this study, the technology at the top level is a Leontief function of the quantities of value added and aggregate intermediate input.

For the model with a Leontief function at the top of the technology nest, the demands for value-added (QVA_a) and the aggregate intermediate inputs ($QINTA_a$) are defined as Leontief functions of the activity level as represented by the following equations.

$$QVA_a = iva_a.QAa \text{ -- } 4.7$$

$$QINTAa = \text{int}\, a_a.QAa \text{ -- } 4.8$$

Where, $a \in$ALEO ($\subset$ A) is a set of activities with a Leontief function at the top of the technology nest, $inva_a$ is quantity of value-added per activity unit, and $\text{int}\, a_a$ is quantity of aggregate intermediate input per activity unit.

Producers may produce output to sell in domestic market or foreign market. Decision of producers to produce for the domestic and foreign markets is governed by Constant Elasticity of Transformation (CET) function which distinguishes between exported and domestic goods leading to captures any time, distance and quality differences between the two products.

In commodity market flow, domestically produced marketable output from each activity contributes to aggregate domestic output by using CES function. Accordingly, the domestic output (QX_c) is allocated to domestic sales (QD_c) and export (QE_c) using constant elasticity of transformation function as follows:

$$QX_c = \alpha_c{}^t.\left[\delta c^t.QEc^{\rho_c{}^t} + (1-\delta_c{}^t)QD_c{}^{\rho_c{}^t}\right]^{1/\rho_c{}^t} \text{ -- } 4.9$$

Where, $\alpha_c{}^t$ is a CET function shift parameter, δc^t is a CET function share parameter, and $\rho_c{}^t$ is a CET function exponent. The shift parameter measures the supply shift in the destination of domestic products based on the profitability of the destination. On the other hand, the share parameter denotes the proportion of exports or domestic sale from domestically produced output, while the exponent shows the elasticity of transformation between the two destinations (Lofgren et al., 2002).

Based on the assumption of imperfect transformability between the two destinations, the export-domestic supply ratio is formulated. Then the optimal mix between exports and domestic sales is explained by export-domestic supply ratio. Export-domestic supply ratio which is stated in the following equation is defined as a function of export-domestic price ratio. This indicates that relative supply of export to domestic increases as the relative prices of export increases because profit maximization drives producers to sell in those markets where they can achieve the highest returns. The returns are based on domestic and export prices and the final ratio of exports to domestic goods is determined by the endogenous interaction of relative prices for these two commodity types (Thurlow, 2004).

$$\frac{QE_c}{QD_c} = \left[\frac{PE_c}{PDS_c} \cdot \frac{1-\delta_c^t}{\delta_c^t} \right]^{1/\rho_c^t - 1} \text{---4.10}$$

Domestically produced commodities that are not exported are supplied to the domestic market. Substitution possibilities exist between imported and domestic goods under a CES Armington specification (Armington, 1969)[10]. So, Composite supply function or Armington function (QQ_c) is function of import quantity (QM_c) and domestic use of domestic output (QD_c). It is specified to absorb imperfect substitutability of imports and domestic output sold domestically. The CES aggregation function in which the composite commodity supplied domestically is produced by domestic and imported commodities entering this function as inputs capture the imperfect substitutability of imports and domestic output sold domestically.

[10] When the domain of the CES function is restricted to commodities that are both imported and produced domestically, then, this function is often known as'' Armington" function, which is named after Paul Armington in honour of his work in 1969 (Lofgren et al., 2002).

$$QQ_c = \alpha_c^q \left(\delta_c^q.QM_c^{-\rho_c^q} + (1-\delta_c^q).QD_c^{-\rho_c^q} \right)^{-\frac{1}{\rho_c^q}} \text{--}4.11$$

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. The shift parameter measures the shift in demand based on the expensiveness of the quantity supplied to the domestic economy. The share parameter signifies the domestic market share of imports or domestically produced output. The Armington exponent shows the elasticity of substitution between the two types of commodities.

Then the optimal mix between imports and domestic output is defined by import-domestic demand ratio ($\frac{QM_c}{QD_c}$) which is function of domestic to import price ratio ($\frac{PDD_c}{PM_c}$). The import-domestic demand ratio 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.

$$\frac{QM_c}{QD_c} = \left[\frac{PDD_c}{PM_c} . \frac{\delta_c^q}{1-\delta_c^q} \right]^{1/1+\rho_c^q} \text{--}4.12$$

Institutional Block

Institutional block constitutes households, enterprises, the government, and the rest of the world. Under this block we model income and expenditure of the above institutions. The primary sources of income for households are factor payments generated during production. And they also receive transfers from other institutions like government, other domestic institutions and the rest of the world. In turn they spend their income on consumption, saving, tax payment and transfers to other institutions. Enterprises in same way get income from factor return and transfers and their expenditure are similar households except there is no consumption in enterprises.

The government earns most of its income from direct and indirect taxes, and then spend it on consumption and transfers to households and other institutions.

The factor income (YF_f) is the sum of activity payment (QF_{fa}) and activity specific wage multiplied by employment level (Lofgren et al, 2002). It defines the total income of each factor.

$$YF_f = \sum_{a \in A} WF_f.\overline{WFDIST_{fa}}.QF_{fa} \text{ -- } 4.13$$

This income then split among domestic institutions after direct factor tax and transfers to rest of the world are paid. 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 to the rest of the world are paid.

$$YIF_{if} = shif_{if}.\left[YF_f - trnsfr_{rowf}.EXR\right] \qquad i \in INSD \text{ ----------- } (4.14)$$

Where, $i \in INS$ is a set of institutions (domestic and rest of the world), $i \in INSD$ ($\subset$ INS) is a set of domestic institutions, $YIF_{i\,f}$ is income to domestic institution i from factor f, $shif_{i\,f}$ is share of domestic institution i in income of factor f[11], and $trnsfr_{i\,f}$ is transfer from factor f to institution i.[12]

The above equation gives reference to the set of domestic institutions in general (households, enterprises, and the government), including the rest of world. Income to domestic nongovernment institutions is then the sum of factor incomes, transfers from other domestic nongovernment institutions, transfers from the government, and transfers from the rest of the world.

[11] To assure that the total factor income is distributed, it is necessary that $\sum_{in \in INSD} shift_{if} = 1$

[12] Ethiopia does not impose direct tax rate for factor (tf_f). Thus, in the above equation, the direct tax rate for factor f is taken as zero.

$$YI_i = \sum_{f \in F} YIF_{if} + \sum_{i \in INSDNG} TRII_{ii'} + trnsfr_{igov}.\overline{CPI} + trnsfr_{irow}.EXR \text{ -----------------------4.15}$$

Where, i ∈INSDNG (=INSDNG. ⊂ INSD) is a set of domestic nongovernment institutions, YI_i is income of institution i (in the set INSDNG), and $TRII_{ii.}$ Is transfers from institution *i.* to *i* (both in the set INSDNG).

Institutions spend their income gained from different sources explained above on different activities. Consumers spend their disposable income i.e. income after tax, transfers and saving on consumption. So, the total value of consumption spending is defined as the income that remains after direct taxes, savings, and transfers to other domestic nongovernment institutions.

$$EH_h = \left[1 - \sum_{i \in INSDNG} shii_{ih}\right].(1 - MPS_h).(1 - TINS_h).YI_h \text{ -----------------------------4.16}$$

Where, i ∈H (⊂ INSDNG) is a set of households, and EH_h is household consumption expenditures

This total value of consumption is on two categories of commodities; consumption of marketed commodities purchased at market price and consumption of home production valued at their opportunity cost.

When we come to investment demand, it is expressed as the base-year quantity multiplied by an adjustment factor (this factor is exogenous in the basic model version). Since the adjustment factor is exogenous, the investment quantity is also exogenous in process. Then, it is framed as:

$$QINV_c = \overline{IADJ}.\overline{qinv_c} \qquad c \in C \text{ \_\_\_\_\_\_\_\_\_\_\_\_\_\_ (4.17)}$$

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

Some adjustments were done on the model to go well with this study. Quantity of fixed investment demand represented by $QINV_c$ in the model was disaggregated to investment demand in electricity sector [QINVE0(C)] and non-electricity sectors (all sectors except electricity) [QINVNE0(C)]. In the aggregated investment demand, if the investment shock is introduced, it increases capital accumulation of all sectors in proportional amount. But in the adjusted model investment shock in electricity sector directly flows to capital accumulation of the sector because the capital accumulation equation was also adjusted in the same way. In line with disaggregation of investment, financing options were also adjusted.

Correspondingly government consumption demand is as well, defined as the base year quantity multiplied by an adjustment factor (this factor is exogenous; consequently the quantity of government is fixed). Its formulation is given as:

$$QG_c = \overline{GADJ}.\overline{qg_c} \qquad c \in C \quad \text{---------} \ (4.18)$$

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

In addition to the above equations, there are equations representing the government revenue and government expenditure. Government is treated as a separate agent with income and expenditure. As its income source government collects taxes and receives transfers from other institutions. Mathematically this can be shown as follows:

$$YG = \sum_{i \in INSDNG} TINS_i.YI_i + \sum_{c \in CM} tm_c.pwm_c.QM_c.EXR + \sum_{c \in C} tq_c.PQ_c.QQ_c + \sum_{f \in F} YIF_{govf} + trnsfr_{govrow}.EXR$$

-- (4.19)

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

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(local currency per foreign currency).[13]

The government uses its income to purchase commodities for its consumption (consumption is fixed in real quantity terms) and to make transfer to other institutions (households and enterprises). Unlike that of government consumption, transfers to domestic institutions are CPI (consumer price index) indexed. Mathematically:

$$EG = \sum_{c \in C} PQ_c.QG_c + \sum_{i \in INSDNG} trnsfr_{i\ gov}.\overline{CPI} \qquad (4.20)$$

Where, EG stands for government expenditure, PQ_c stands for composite price, QG_c stands for government consumption demand for commodity, $trnsfr_{igov}$ stands for transfers from the rest of the world (ROW) to the government, and CPI stands for consumer price index.

In this block apart from the above equations, there is equation specifying Transfers between domestic nongovernment institutions where the payment is made as a fixed share of total institutional incomes net of direct taxes and savings.

Production is linked to demand through the generation of factor incomes and the payment of these incomes to domestic institutions. Balance between demand and supply for both commodities and factors are necessary to reach equilibrium in the model. This balance is imposed on the model through a series of system constraints

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[13] In Ethiopia, direct tax from factors, ''value-added taxes'' on activities, activity taxes and export taxes are excluded from the equation specifying the government revenue sources. It is because these taxes are not practical in Ethiopia.

(Thurlow, 2004). The following part gives a detail discussion on equilibrium condition.

System constraints and macroeconomic closure

Equilibrium in the goods market requires the equality of demand for commodities and supply. Aggregate demand for a good comprises consumption spending, investment spending, and export and transaction services demand. Supply in turn includes both domestic production and imported commodities. Equilibrium is attained through the endogenous interaction of domestic and foreign prices, and the effect that shifts in relative prices have on sectoral production and employment, and hence institutional incomes and demand (Thurlow, 2004). There are different closure rules to attain equilibrium condition in factor market and output market i.e. factor market and macroeconomic closure rules. This study selected the model closures that are applicable to the Ethiopian economy.

The equilibrium condition of factor demand and supply is dependent on how the relationship between factor supply and wages is defined.

$$\sum_{a \in A} QF_{fa} = \overline{QFS_f} \qquad \text{--------------- (4.21)}$$

Where, $\overline{QFS_f}$ represents quantity supplied of factor f.

This fixed $\overline{QFS_f}$ is dependent on the closure rule. It works if factors are fully employed, otherwise not. Since, in the above specification, all demand variables are flexible and supply is held fixed, the economy-wide wage, WF, plays the market clearing role in a setting with perfect factor mobility across activities. The equilibrium is highly dependent on how the relationship between wages and factor supply is defined.

In this study we assumed land is fully employed and mobile across sectors; and capital and skilled labor are fully employed and activity specific. The implication of full employment of land, capital and skilled labor is the fixation of their quantity. Semi skilled and unskilled labor is freely mobile and unemployed because there is a room for unemployment so its employment is flexible; therefore, wages are fixed in real terms and supply passively adjusts to match demand. The mobility of unskilled labor and land across sectors implies that they can be employed in different activities whereas immobility of capital and skilled labor across sectors implies it is activity specific and sector-specific wages adjust to ensure that demand for capital and skilled labor is equal total supply for capital and skilled labor.

There are three macro balances: Government balance, external balance and saving investment balance. For government balance we have three closures: the first closure assumes that government savings (the difference between current revenues and expenditure) is a flexible residual while tax rates are fixed, second closure assumes that the direct tax rates on households and enterprises are flexible to allow for an adjustment in revenue and thereby maintain government savings which is fixed. The direct tax rate on non-government institutions is increased by a fixed number of percentage points (Thurlow et al, 2002), whereas the third closure assumes that the tax rates are multiplied by a fixed scalar (scaling direct tax) and government savings are fixed. In each of the three options it is assumed that government consumption expenditure is held fixed either in real terms or as a share of total absorption. In this study the first closure where the direct tax rates are held fixed and government saving is flexible (thus, the change of this variable will balance the government account) is used.

For external balance there are two closures: exchange rate is flexible, foreign savings are fixed and exchange rate is fixed, foreign savings are flexible. For this study the first closure is chosen because foreign saving is one of the options to finance power infrastructure investment. So, it is held fixed and we shocked it by the amount of fund required for this investment. The mathematical formulation of the current account balance (which is expressed in foreign currency) is given as:

$$\sum_{c\in CM} pwm_c.QM_c + \sum_{f\in F} trnsfr_{rowf} = \sum_{c\in CE} pwe_c.QE_c + \sum_{i\in INSD} trnsfr_{irow} + \overline{FSAV} \quad \text{--------} (4.23)$$

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. Therefore, real exchange rate plays the role of equilibrating the current account balance.

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 or whether investment is considered to be savings-driven (Thurlow et al, 2002). Therefore, closures are either investment driven (the value of savings adjusts) or savings-driven (the value of investment adjusts) (Lofgren et al, 2002).In this study the saving driven closure is used.

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

-- (4.24)

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 cater for imbalance, the S-I balance also has an optional addendum in 'WALRAS' which is valued at zero if the model is in equilibrium (balanced).

Finally, the consumer price index is chosen as the numéraire such that all prices in the model are relative to the weighted unit price of households' initial consumption bundle. The model is also homogenous of degree zero in prices, implying that a doubling of all prices does not alter the real allocation of resources.

4.3.2. Between periods or Dynamic CGE block

In the previous section we have described the within-period or static component of the model. However, the impact of policy-changes includes dynamic aspects, such as the inter-temporal effects of changes in investment and the rate of capital accumulation. In order to investigate in more detail the relationship between policy-changes and factor accumulation the static model is extended to a dynamic recursive model. In the extended part of the model labor supply will be determined exogenously (updated by the population growth rate, i.e. as population grows, the total labor supply increases at the same rate) while capital accumulation is determined endogenously (In a given time period the total available capital is determined by the previous period's capital stock and investment spending). Then new capital will be distributed among sectors based on each sector's initial share of aggregate capital income (Thurlow, 2004).Full specification of each dynamic equation is given in Appendix I.

4.4. Limitations of the Model

Regardless of the great importance of the outputs of such models to policy makers, they are not free of limitations. It incorporates *ad hoc* assumptions about the price responsiveness of supply and demand. Assumption of a representative agent does not reflect individual behaviours. The key elements that drive the results of a scenario are not always transparent. The model and its associated databases are costly to build and maintain (Scrieciu, 2006).The model is complex and requires skill.

CHAPTER FIVE

SIMULATIONS AND RESULTS

5.1. Descriptions of Simulations

Investment on power sector in Ethiopia is planned to increase the power generation capacity of the country from 876.9 MW in 2009 to 133038MW in 2016. As a result, actual energy production capability of the country will increase from 3701.1 GWH in 2009 to 32656 GWH at the end of 2016. To achieve this objective, the investment spending on infrastructure for electricity has been growing at 30% on average for each year from 2010 to 2016 compared to 2009[14]. This growth rate is computed from Table 3.4 and 3.7 in chapter three.

As the supply of electricity increases (power outages decreases), total factor productivity of the firms increase because investment on electricity has positive externality to the industrial and service sectors. In general, infrastructure contributes some 53% of total factor productivity of firms in Ethiopia (Eberhand et al, 2011; Foster et al, 2010). According to Escribano et al (2009), 20% improvement in infrastructure in Ethiopia leads to improvement of average productivity of firms by 6.3%.

From infrastructure contribution to total factor productivity of private firms, electricity covers almost 80%. Therefore, it is difficult to think of any firm in either industry or services that would not rely on electricity. Looking at the demand section of the activity level in the 2005/06 Ethiopian SAM, the industrial and services' sectors are the main users of electricity (Appendix B). Agricultural activities, fetching water and real estate activities do not use electricity in the production. Inadequacies in

[14] We did not include spending expected to be financed by EEPCo own sources

electricity provision may disrupt the production process in these sectors, and cause productive factors to lie idle that would easily lead to decreased productivity.

To see productivity impact of investment on electricity, we used elasticity of total factor productivity with respect to electricity investment estimated in Mali. Both Ethiopia and Mali are among least developing countries in Africa. They both are land locked countries. People of the both countries are predominantly engaged in agricultural activities. Contribution of agriculture to GDP is more than 40% in both countries. More than 50% of productivity constraint of firms in both countries is caused by electricity shortage (Eberhard et al, 2011). A delay to obtain electricity connection in 2006/07 was 48.4 days in Mali and 44.22 days in Ethiopia. Firms that use their own generator in the same year were 23.78% in Mali and 25.63 % in Ethiopia. Number of power outages in typical months in 2006 was 4.16 in Mali and 5.01 in Ethiopia. Average hours of power outages in Ethiopia was 3.88 and in Mali 3.89 hours (WDI, 2009). Therefore, based on these similarities, we used the elasticity of total factor productivity with respect to electricity used by Estache et al (2007) to analyse the impact of infrastructure spending in Mali. He used elasticity of 0.015 for the exporting subsector of agriculture, 0.02 for mining and gas, 0.1 for industry, 0.075 for construction and 0.055 for private services sector for 1% increase in investment in electricity. We did not increase productivity of agriculture sector since this sector does not use electricity. So, 30% increase in investment in electricity results in 3%, 1.65% and 2.25% improvement in TFP of industrial, service and construction sectors, respectively.

To examine the impact of investment in electricity on the Ethiopian economy and thus to achieve the objectives of the study the following simulations are considered:

Simulation 0: The base case scenario is established to serve as a reference in an absence of any policy shock and serves as a benchmark for policy evaluation (assumes the status qua continues). Thus, the result of the base line simulation is used as the benchmark value so as to compare the values of different variables after the policy shocks.

Simulation 1: Increase in investment in electricity that fully financed through increased foreign saving rate (loan) + increase in TFP of industrial and service sectors shock. If domestic household and enterprise saving and other investment (non electricity investment) grow at base line rate, to finance investment in electricity foreign saving rate grows at 26% each year.

Simulation 2: Increase in investment in electricity that fully funded by increased domestic household and enterprise saving rate + increase in TFP of industrial and service sectors shock. If foreign saving rate and non- electricity investment grow at base rate, domestic household and enterprise saving rate has to grow at 12.7%.

Simulation 3: Increase in investment in electricity investment financed partly through increased foreign saving rate (loan) and partly through increased domestic household and enterprise saving i.e. (50% of it by foreign saving and 50% of it by domestic household and enterprise saving) + increase in TFP of industrial and service sectors shock. In the case where both foreign and domestic households and enterprise savings are used they have to grow at 15% and 7.9%, respectively. These shocks are introduced for seven years (2010-2016).

5.2. Interpretation of Results

In this section, we present the detailed results of our simulation and their interpretation. The analysis is essentially on major issues; such as, impacts on macroeconomic indicators, trade balance, major economic sectors, factor income and households' income, consumption and consumption expenditure.

5.2.1. Effects on Macroeconomic Variables

In Table 5.1 we present the summary of the results from our simulation exercise for the major macroeconomic variables. These variables are real GDP at factor cost (GDPFC2), fixed investment (FIXINV), private consumption (PRVCON), government consumption (GOVCON), real exports and real imports.

In all simulations, the macroeconomic variables have shown positive changes. In simulation 1, a real GDP at factor cost reveals 1.32% increase from base line simulation. It grows by 11.96%. This is largely driven by rising in real investment and private consumption. Real investment and private consumption increase by 6.09% and 1.53% compared to base line simulation, respectively (Table 5.1).

Compared to the other simulations in this study, the growth rate of consumption is highest. This might be due to the fact that, inflow of additional resources to the economy from the rest of the world increase domestic consumption. When electricity investment is financed through increased foreign saving rate (loan), it increases financial inflow to the country which in turn leads to a raise private consumption. Increase in private consumption in turn contributes more to GDP growth.

In simulation 2, as shown in Table 5.1, real GDP at factor cost grows at 1.56% more than base line simulation. It grows by 12.21%. It is the highest growth rate compared to simulation 1 and 3. Increase in growth rate of GDP, in this case, is explained by an increase in real investment and real exports though there is a lower growth rate of real private consumption. Real fixed investment and real export increase by 6% and 4.34% compared to the base line simulation, respectively. So, increase in real export and fixed investment offsets decrease in private consumption and leads to increase in growth rate of real GDP at factor cost. Investment on electricity, therefore, financed through increased domestic household and enterprise saving rate has better contribution to real GDP growth than investment on electricity financed through increased foreign saving (loan).

The lowest growth rate of private consumption is, however, registered in simulation 2. It grows at negative rate (0.14% less than base line simulation). Since investment on electricity is financed through increased households' and enterprise savings rate, that part of disposable income to be spent on consumption goes down, which in turn explains the decrease in the real private consumption.

Finally, in simulation 3, real GDP at factor cost increases by 1.55% compared to the base line simulation. It grows by 12.14%. The reason for increase in growth rate of real GDP is an increase in growth rate of fixed investment and real export. They increase by 6.5% and 2.65% more than one obtains in the base line simulation, respectively. Investment on electricity financed with partly by domestic household and enterprise saving rate and partly by foreign savings rate results in better GDP growth rate than investment fully financed through increased foreign saving rate. It has nearly the same growth rate with investment fully financed by increased domestic household and enterprise saving. Similarly, real private consumption grows at positive growth. It rises by 0.65% compared to base line simulation.

Table 5.1: Impact on macroeconomic variables

Average % change per year

Variables	Initial	Sim0	Sim1	Sim2	Sim3
PRVCON	338.61	9.2	10.73	9.06	9.85
FIXINV	85.49	12.45	18.53	18.45	18.5
GOVCON	31.82	5.7	5.7	5.7	5.7
EXPORTS	52.14	20.07	20.34	24.41	22.72
IMPORTS	-126.51	12.39	16.49	15.14	15.71
GDPFC2	354.95	10.64	11.96	12.21	12.14
REXR	1	-1.59	-3.93	-2.12	-2.88

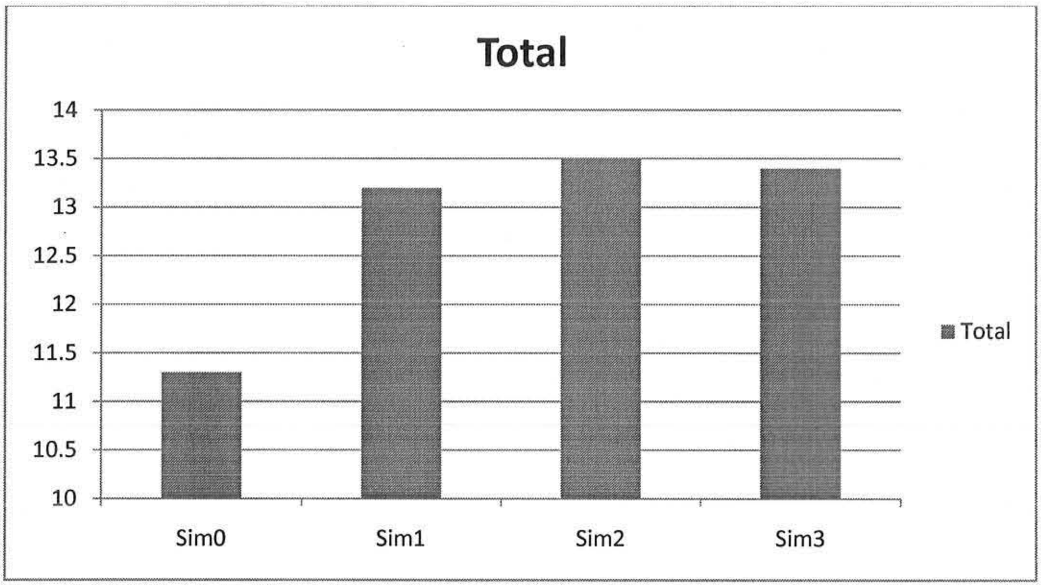
Average % change from base line simulation (simulation 0)

variables	Initial (in billion birr)	Sim1	Sim2	Sim3
PRVCON	338.61	1.53	-0.14	0.65
FIXINV	85.49	6.09	6.00	6.05
GOVCON	31.82			
EXPORTS	52.14	0.27	4.34	2.65
IMPORTS	-126.51	4.09	2.75	3.32
GDPFC2	354.95	1.32	1.56	1.55

Source: Simulation results

In general, GDP at factor cost has increased by 1.32%, 1.56% and 1.55% in simulations 1, 2, and 3 compared to base line simulation (it grows by 11.96%, 12.21% and 12.14% in the respective simulations). We can also explain increase in growth rate of real GDP using disaggregated activity production level shown in Figure 5.1. Comparing Table 5.1 and Figure 5.1, indicate that the growth rate of aggregate activity production levels has also increased in all simulations. It has grown by 11.3%, 13%, 13.3% and 13.1% in simulations 0, 1, 2 and 3, respectively. This positive growth rate comes partly from productivity gain to industrial and services sectors and direct impact of electricity investment on economic activity.

Figure.5.1. % change in disaggregated activity production levels (QTABPY)



Source: Simulation results

5.2.2. Impact on Trade Balance

In simulation 1, as it is explained in section 5.2.1, the real export increases by 0.27% compared to base line simulation (Table 5.1). It is the least growth rate compared to simulation 2 and simulation 3. This might be due to an appreciation of real exchange rate. Increase in foreign loan to the economy appreciates the real exchange rate by raising price of non tradable goods as the increased financial resources inflow increases spending on non tradable goods and services. In fact, the real exchange rate appreciates by 3.93%. Appreciation of the real exchange rate may reduce competitiveness of the trade sector. Since there is an inflow of funds, we will need to import more and export less. In other words, export firms become less profitable because their revenue declines as they sell at the world market price (in dollars) and their costs measured (in local currency) rise. As a result, economic resources may move from the tradable to the non tradable sector resulting in a contraction of the tradable sector and expansion of the non tradable sector. As can be seen from Appendix C, the real exports of all activities have declined. However, real exports of leather, textile, chemicals, chat, crops, dairy and pulse, among the others, have declined at the highest rate.

Though the real exchange rate is appreciated, the real export grew at a positive rate. This could easily be attributed to the total factor productivity effect of investment in electricity on industrial and service sectors that improves their output. So, positive supply side effects of this investment on the productivity of the private sector overcome the possible negative impact of the appreciation of the real exchange rate. That is as productivity increases, producers will be more competitive in foreign markets and may offset possible negative effects on competitiveness of domestic firm emanating from an appreciation of the real exchange rate.

Unlike the real export, the real import has registered the greatest growth rate in simulation 1. It increases by 4.09% compared to base line simulation (Table 5.1). This may be partly explained by increase in resource inflow that increases domestic demand. According to appendix D, real imports of machinery, leather, dairy, crops, wheat and non metallic commodities have risen more than other commodities.

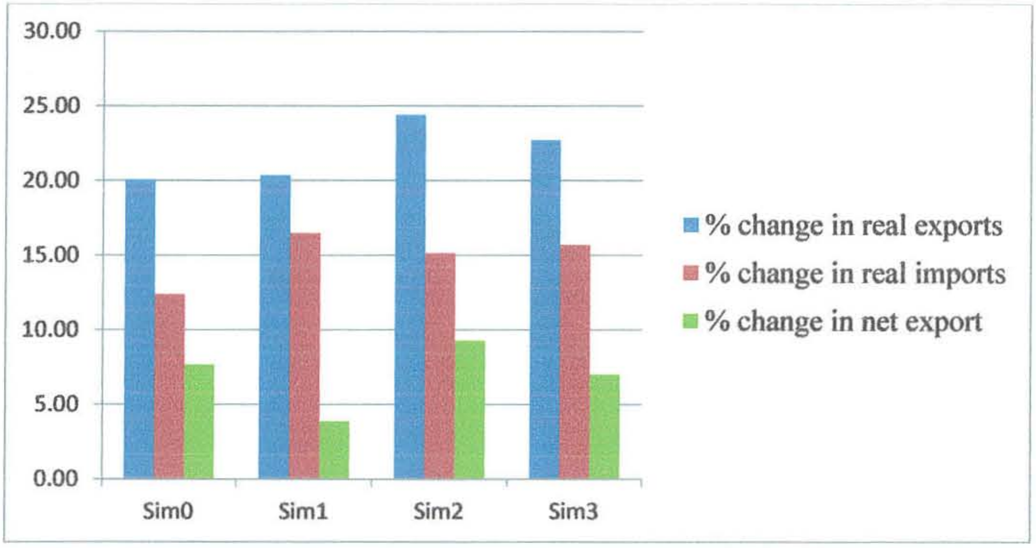
In simulation 2, real export grows by 24.41%. This led to be 4.34% more than the baseline simulation. It is the greatest growth rate compared to simulation 1 and simulation 3 because possible combined effects of increase in factor productivity and the least appreciation of the real exchange rate improve real export. Import has, however, the least growth rate in this simulation with a growth rate of 15.14% (Table 5.1).

In simulation 3, the growth rate of real export is greater than that obtained in simulation 1 because the appreciation of the real exchange rate is lower. It has grown by 22.71% (2.38% more than simulation 1). Real import grows by 15.71% (Table 5.1). Real exchange rate has appreciated by 2.12%. So, the possible combined effect of increase in total factor productivity and lower appreciation of the real exchange rate result in positive growth of real export.

Using percentage change in real exports and real imports from simulation results we can analyse the impact of investment on electricity on percentage change of trade balance of the country. In all simulations, the average growth rate of exports is greater than average growth rate of imports. This will lead improvement in average growth rate of trade balance. As we can see from Figure 5.2, in simulation 1 and simulation 3, the growth rate of real exports is lower than growth rate in simulation 2. In contrast, growth of the real import is greater in simulation 1 and 3. As a result, trade balance deteriorates more in simulation 1 and simulation 3.

In general, there is improvement in the growth rate of trade balance in the case of simulation 2. Financing investment on electricity by using domestic household and enterprise saving increase percentage change of trade balance than financing investment on electricity through increased foreign saving (foreign loan).

Figure 5.2: Average % change in trade balance



Source: simulation results

5.2.3.Sectoral Effects of Investment on Electricity

We can also analyse the impact of investment on electricity on the sectoral output using GDP at factor cost disaggregated by activity. Average percentage change in output from base line simulation of all sectors is depicted in Table 5.2. Output of all activities in the agricultural, industrial and service sectors are aggregated to get total output of the sectors for the years 2009 to 2016. Then average percentage change in output for each sector is calculated from aggregate output growth. Accordingly, among the sectors, the largest expansion is shown by the industrial sector. It has increased by 2.1%, 3.1% and 2.5% in simulation 1; simulation 2 and simulation 3 respectively (Table 5.2). This is because the industrial sector is one of the major users of electricity as an intermediate input in its production. Therefore, total factor productivity of industrial sector improves more following investment on electricity shock and it explains expansion of the output in the sector. Among the activities in the sector, output of metal, machinery, vehicles, electronic equipments and paper manufacturing have recorded the fast growth rates. The highest growth rate of output is, however, expected in metal manufacturing (appendix E1). It grows at 4.35%, 8.31% and 6.67% in simulation 1, 2, and 3 compared to base line simulation, respectively.

In terms of percentage change of sectoral output, the service sector is the second with percentage change of 2%, 2.6% and 2.4% in 1, 2 and 3, respectively. Among the subsectors the construction, transport and whole sale and retail trade registered higher growth rate. The largest output growth rate is, nevertheless, registered by the construction sector. It increased to 17.51% in simulation 1 from 12.21% in the base line simulation. It has also grown at 17.38% and 17.45% in simulation 2 and 3, respectively (Appendix E2).

The investment on electricity, on the other hand, has the least effect on the agricultural sector because agricultural sector does not use electricity as an intermediate input in its production processes. It has the least growth rate. Its output rises by 0.3% and 0.2% in simulation 1 and simulation 3, respectively. But it declines in simulation 2. That may be due to decrease in domestic consumption. It is also the least favoured by the investment on electricity.

Table 5.2: Sectoral impact of investment on electricity

Sectoral impact (average % change per year)

Sectors	Sim0	Sim1	Sim2	Sim3
Agriculture	7.2	7.5	7.1	7.4
Industry	13.9	16.0	17.0	16.4
Service	13.4	15.4	16.0	15.8

Average % change from base line simulation (simulation 0)

Sectors	Sim1	Sim2	Sim3
Agriculture	0.3	-0.1	0.2
Industry	2.1	3.1	2.5
Service	2.0	2.6	2.4

Source: Own computation from simulation results

5.2.4. Impact on Factor Income

In relation to returns to factors of production, the results from the CGE model are provided in the Table 5.3. Aggregate income of factors of production has improved in all simulations. Increase in returns of factors of production is because of increase in output of activities in all the sectors (industry, service and agriculture) except agricultural output in simulation 2. However, the higher growth rate in aggregate factor income is obtained in simulation 1 and 3 compared to simulation 2. The average growth rate of aggregate returns rises from 10.97% in simulation 2 to 10.99% in simulation 1 and simulation 3. It has grown by 1.09% more than baseline simulation and by 0.02% more than simulation 2 and 3. Therefore, returns of all the factors increase more when investment is financed with increased foreign saving rate and financed partly with increased foreign saving rate and domestic household and enterprise savings rate than fully financed with increased domestic household and enterprise savings rate, since in the former case there is additional resource inflow to our country and it may also be due to the rise in output price of non tradable goods which may increase the returns of factors.

Table 5.3: Impact on factor income (Average % change and % change from simulation 0)

Variables	initial	Share	Sim0	Sim1	Sim2	Sim3
Labor	174	49%	9.42	9.90	10.02	9.97
Capital	110.3	31%	9.59	12.04	12.37	12.24
Land	39.7	11.2%	11.17	11.43	10.80	11.15
Livestock	30.8	9%	12.17	12.98	11.60	12.2
Total	355	100%	9.9	11.0	10.97	11.0

Variables	Initial	Share	Sim1	Sim2	Sim3
Labor	174	49%	0.48	0.60	0.55
Capital	110.3	31%	2.44	2.78	2.65
Land	39.7	11.2%	0.26	-0.37	-0.02
Livestock	30.8	9%	0.81	-0.57	0.03
Total	355	100%	1.10	1.07	1.10

Source: own computation from simulation results

Among the factors of production, the return of capital grows at the fastest rate. It grew by 12.04%, 12.37% and 12.24% in simulations 1, 2 and 3, respectively. Compared to the baseline this has grown by 2.44%, 2.78% and 2.65% more in the respective simulations. The reason could emanate from the activities that are relatively more capital intensive. Investment on electricity affects returns of capital directly and indirectly. A larger proportion of investment spending on electricity is on capital stock that increases demand for capital input. So, capital owners will directly benefit from the investment on electricity. This, however, also affects the returns of capital by affecting industrial and service sectors; and since these sectors are capital intensive compared to agricultural sector. As a result, fast growth in these sectors can result with improvements in returns of capital.

As shown in Table 5.3, aggregate income of labor has recorded positive growth. It grows at 9.9%, 10.02% and 9.97% in simulation 1, simulation 2 and simulation 3, respectively. It has increased by 0.48%, 0.6% and 0.55% in simulation 1, 2, and 3 compared to base line simulation. Therefore, it has grown fast in the case of investment on electricity financed by increased domestic household and enterprise saving, since increase in return of semi skilled and unskilled labor offsets decrease in returns of agricultural labor (Table 5.4). Increase in income of skilled labor is may be due to expansion in tradable sector while decrease in income of agricultural labor is due to contraction of agricultural output.

Table 5.4: Impact on labor income (average % change from base line simulation)

Labor group	Initial(billion birr)	Share	Sim1	Sim2	Sim3
Skilled labor	77.5	44.5	0.25	1.25	0.84
Unskilled labor	39.4	22.7	1.05	0.63	0.84
Agricultural labor	57.1	32.8	0.33	-0.32	0.01

Source: simulation results *skilled labor –includes both skilled and semi skilled

Returns of land and livestock rise at a lower rate in all simulations even negative in simulation 2. This is due to the fact that increase in production of industrial and service sectors result in more increase in income of labor and capital and does not increase return of land and livestock.

5.2.5. Impact on Households

We can also analyze the impact of investment on electricity households using household income, consumption, consumption expenditure.

5.2.5.1. 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 analyse the impact of investment on electricity household income using Table 5.5.

According to the table, aggregate household income has registered positive growth. It grows at 10.57%, 10.53% and 10.56% in simulations 1, 2, and 3, respectively. That is compared to the base line simulation it is increased by 1.08%, 1.04% and 1.07 % in simulation in the respective simulations. Therefore, higher household income growth is achieved when investment on electricity is financed with increased foreign saving rate then by increased domestic household and enterprise saving rate. But, investment on electricity financed simultaneously i.e. partly by increased domestic household and enterprise saving rate and partly by increased foreign savings rate has nearly the same impact with first simulation on aggregate household income. We have also seen the impact of this investment on poor and non poor households by aggregating income of households in different agro ecological zones depicted in Appendix F. Growth rate of income of both poor and non poor households in both urban and rural areas has improved (Table 5.5). In general the investment on electricity will result in substantial increase in real incomes of all households except poor households in high land cereal agro ecological zone (Appendix F).

Table 5.5: Impact on household income

Average % change per year

households	Initial (in billion Birr)	Sim0	Sim1	Sim2	Sim3
Rural poor	73.93	9.93	10.56	10.24	10.4
Rural non poor	261.08	9.63	10.78	10.87	10.83
Urban poor	3.83	8.8	10.11	10.51	10.33
Urban non poor	35.54	7.65	8.67	9.05	8.88
Total		9.49	10.57	10.53	10.56

Average % change from base line simulation

household	Initial	Sim1	Sim2	Sim3
Rural poor	73.93	0.31	0.63	0.47
Rural Non poor	261.08	1.24	1.15	1.20
Urban Poor	3.83	1.71	1.31	1.53
Urban Non poor	35.54	1.4	1.02	1.23
Total	374.38	1.08	1.04	1.07

Source: Own computation from simulation results

5.2.5.2. Impact on Household Consumption Expenditure

Households spend their income on consumption after they save and pay taxes and transfers to other institutions.

As we can see from Table 5.6, compared to the base line simulation, household consumption has improved more in simulation 1. It has increased by 1.55% and 0.75% in simulation 1 and simulation 3, respectively. Unlike in simulation 1 and simulation 3, household consumption has recorded negative growth in simulation 2. Total average consumption of all households in both rural and urban areas has declined by 0.16%. Decline in their consumption in general is due to increase in marginal propensity to save. The urban non poor and rural poor households have recorded negative growth. Decrease in consumption of the urban non poor households is due to increase in saving rate while decrease in the consumption of the rural poor may be due to decrease in income of agricultural labor.

Therefore, household consumption raises more with investment on electricity that is financed through increased foreign savings than in the case where it is financed through increased domestic households' and enterprises saving, since financing investment on electricity through increased foreign saving increases resource inflow to our country. Nevertheless, as foreign savings are in the form of loans that are to be repaid, it may increase consumption for the short time (temporary). Thus, household income and consumption may be chosen as the preferred indicators for the more enduring gains from increased foreign savings.

Table 5.6: Impact on household consumption

Average % change per year

households	Initial(billion birr)	Sim0	Sim1	Sim2	Sim3
Rural poor	70.18	9.67	10.29	9.11	9.68
Rural non poor	237.96	9.19	10.35	9	9.65
Urban poor	3.43	8.24	9.54	7.92	8.71
Urban non poor	27.04	6.31	7.31	3.55	5.43
total	338.61	9.2	10.75	9.04	9.95

% change from base line simulation

	Initial	Share	Sim1	Sim2	Sim3
Rural poor	76.72	22.7	1.02	-0.3	0.46
Rural non poor	146.9	70.3	1.63	0.08	0.87
Urban poor	3.43	1.0	2.1	0.18	1.1
Urban non poor	27.04	8.0	2.27	-2.24	0.32
Total	338.61	100	1.55	-0.16	0.75

Source: From simulation results

It also affects consumption expenditure of household by affecting their consumption. Consumption expenditure is the product of commodity consumed by households and average output price. In simulation 1, consumption expenditure of all households records a positive growth. Aggregate consumption expenditure grew at 10.1% (1.05% more than the one obtained in the base line simulation). It is the fastest growth rate compared to simulation 2 and simulation 3. Financing the investment on electricity by increased foreign savings (loan) allows each of the domestic household groups to increase their consumption expenditure at a higher rate (Appendix G).

The negative growth rate of aggregate consumption expenditure is, however, recorded in simulation 2. It has declined by 0.47%. In general, growth rate of Consumption expenditure of almost all household categories declines partly due to increase in saving rate and decrease in income of some groups of households. In simulation 3, the growth rate of household consumption expenditure is in between simulation 1 and simulation 2. Except for urban non poor and some rural households, consumption expenditure of all households' has risen (Appendix G).

We have also aggregated households in to poor and non poor both in urban and rural areas. From the results in Table 5.7 below, in simulation 1, consumption expenditure of poor and rich household both in the rural and urban areas has increased. Urban poor and rich households' consumption expenditure has increased by 1.3% and 1% respectively. Consumption expenditure of rural poor and non poor households has grown by 1.16% and 0.62%. Nevertheless, consumption expenditure of both poor and rich households in both rural and urban areas has registered negative growth in simulation 2. In simulation 3, except urban non poor it has grown at positive rate because urban non poor households save more.

Over all, compared to the other simulations consumption expenditure has grown at the highest rate in simulation 1.

Table 5.7: Impact on aggregate house consumption expenditure (% change from simulation 0)

Households	Initial (in billion birr)	Share (%)	Sim1	Sim2	Sim3
Rural poor	70.18	20.7	0.62	-0.56	0.01
Rural non poor	237.96	70.3	1.16	-0.19	0.46
Urban poor	3.43	1.0	1.30	-0.32	0.47
Urban non poor	27.04	8.0	1.00	-2.76	-0.88
Total	338.61	100	1.05	-0.47	0.26

Source: simulation results from CGE model

CHAPTER SIX

CONCLUSIONS AND POLICY IMPLICATIONS

6.1. Conclusions

In this study we attempted to examine economy wide impact of investment on infrastructure for electricity using a recursive dynamic CGE model. The study used an updated version of the 2005/06 EDRI Social Accounting Matrix. We used three simulations to evaluate economy wide impact of this investment. Such as, investment on electricity fully financed with increased foreign saving rate (loan), investment on electricity fully financed through increased domestic households' and enterprise savings rate and investment on electricity financed partly by increased domestic saving and partly by increased foreign savings rate (50% of spending by domestic household and enterprise saving and 50% of it by foreign loan).

The descriptions part in chapter three indicated that investment spending on electricity has increased significantly after 2009. Investment expenditure in this sector is planned to grow by 30% on average from 2010 to 2016. This is stipulated to increase electricity generation capacity of the country to 13,3038MW in 2016 from the mere 876.9 MW that was produced in 2009. As a result, actual energy production capability of the country will increase to 32656 GWH. However, the main challenge of this huge investment is financing sources.

The paper assessed the impact of investment on electricity on aggregate macroeconomic variables, net trade, sectoral output, factor income and household income, consumption and consumption expenditure.

The results of investment on electricity financed by increased foreign saving result in positive changes in the macro economy, as represented by real GDP at factor cost. It has increased by 1.32% compared to the base line simulation. Sectoral effects and disaggregated activity by subsector also confirm increase in output. Nevertheless, the growth rate of real GDP is lower compared to investment on electricity that is financed by increased domestic household and enterprise saving and a combination of domestic (household and enterprise) and foreign savings due to slower growth in real export. It has also a positive impact on household consumption, consumption expenditure, and factor and households income. The income and consumption expenditure of both poor and rich households in the urban and rural areas would rise substantially. However, a scheme of investment on electricity that is fully financed by increased foreign loan, deteriorates the average growth rate of trade balance by appreciating the real exchange rate, and leads to contraction of real exports.

The largest growth rate of real GDP is revealed in the case of investment on electricity financed by increased domestic household and enterprise saving. It has risen by 1.56%. This is due to the fact that increase in growth rate of real export and fixed investment offset decrease in real private consumption. Moreover, this investment has positive effects on output of the industrial and service sectors. It also improves factor income (except for agricultural labor due to decline in output of agriculture) and household incomes. However, it has negative effects on household consumption and consumption expenditure.

In the last simulation, where the investment on electricity is financed partly by domestic household and enterprise saving and partly by foreign loan, GDP at factor cost has grown at positive rate. It has increased by 1.55%. It has nearly the same growth rate as the investment on electricity that is fully financed by increased domestic household and enterprise saving. Similarly, Income of households and factors of production have risen in this simulation. They have increased almost by the same growth rate with investment that is fully financed by increased foreign saving rate. Average aggregate household consumption and consumption expenditure have also grown at positive rate. Nonetheless, consumption expenditure has declined for the urban non poor and some rural households in different agro ecological zones.

6.2. Implications

This study has some useful implications for policy and future research in relation to investment on electricity.

Firstly, creating favourable conditions for the industrial sector is one of the pillar strategies for sustaining the rapid and broad based economic growth in our growth and transformation plan. Therefore, investment on electricity would be valuable to ensure faster and enhanced development of this sector.

Secondly, investment financed by increased foreign saving (foreign loan) will be associated with appreciated real exchange rate. Appreciation of real exchange rate may reduce competitiveness of trade sector by contracting export sector. The results of this paper attest the same conclusion that investment on electricity financed by increased foreign loan, compared to investment on electricity financed with domestic household and enterprise saving and combination of both (50% of it by domestic household and enterprise saving and 50% of it by foreign financing), lead to higher appreciation of the real exchange rate contributing to slower growth in real export though it grows at positive rate due to positive factor productivity effect. As a result, even though it increases income and welfare of households, it deteriorates average growth rate of net export that could be taken as the reason for lower growth rate of real GDP at factor cost. In addition, since foreign loan is expected to be repaid, it would increase indebtedness of the country.

On the other hand, meeting the full financing requirements of this investment through mobilizing domestic household and enterprise saving will be challenging. To finance the planned investment on electricity, if foreign saving and non electricity investment (investment on all other sectors) grow at base rate, domestic household and enterprise saving rate has to grow at 12.7%. Though it revealed the highest growth rate of real GDP, it is difficult to achieve this saving rate as compared to low saving rate in Ethiopia.

So, financing investment on electricity partly by increased domestic household and enterprise saving rate and partly by increased foreign saving rate would be worthwhile.

Thirdly, to mobilize finance by attracting domestic saving, it needs development of sound policy that ensures positive interest rate to the savers. Therefore, government should develop resonant policy to create a centre of attention.

Finally, this study focused only on foreign loan and domestic household and enterprise savings to finance the investment on electricity. It also used elasticity of TFP with respect to investment on electricity estimated for Mali. Further research should be conducted on this investment and its impact on economy including other financing alternatives such as direct and indirect taxes and estimating TFP with respect to investment on electricity of industrial and service sectors in Ethiopia.

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Appendices

Appendix A: Planned investments, total cost for each project and completion year in 2011-2015

no.	project	capacity (MW)	Investment (in Million US$ At 2010 Prices)	completion yr	Capability inGWh per year
1	Adama 1 Wind Park	51	117.00	2011	161
2	Medium Speed Diesel (MSD1)	120		2011	566
3	Ashegoda Wind Park	120	292.84	2012	197
4	Messobo/Harena Wind Park	51	127.00	2012	104
5	Ayisha wind Park	300	688.24	2012	592
6	Aluto Langano II Geothermal	75		2012	428
7	Amerti Neshe HEPP Project	97	139.53	2013	198
8	Debre Birhan wind Park	100	117.00	2013	197
9	Asela wind Park	100	117.00	2013	197
10	Gibe III HEP Project	1870	1,361.30	2013	6240
11	Genale Dawa III	254	297.92	2014	1640
12	Chemoga Yeda I and II	280	329.12	2015	1415
13	Halele Warabesa HEPP Project Stage 1 & 2	422	422.43	2015	1847
14	Geba I and II	372	436.76	2015	1788
15	Genale Dawa VI	246	446.74	2015	1575
16	Gibe IV	1472	1,925.09	2015	6750
17	Gojeb	150	281.70	2015	450
18	Renaissance Dam	5250	4,534.54	2015	NA
	Total 2011 - 2015	11,330.01	11,634.20		

Source:EEPCo, 2011

Appendix B: Electricity use in different activities of industry and service sectors

Industrial activity	Electricity use ('000000 birr)	Service sector activities	Electricity use ('000000 birr)
Mining and Quarrying	37.876	Education	35.611
Grain mill production	13.291	Communication	4.656
Other food manufacturing	37.076	Transport	24.74
Beverage manufacturing	17.698	Hotel and catering	99.21
Tobacco manufacturing	769.2	Whole sale & retail Trade	187.01
Sugar manufacturing	5.383	Construction	7.282
Wood manufacturing	1.927	Business services	0.744
Vehicle manufacturing	1.202	Public administration	169.05
Wearing apparel	1.425	Other private services	4.842
Leather manufacturing	11.327	Milling services	93.721
Textile manufacturing	37.223		
Electrical Equipment	0.055		
Machinery and Equipment manufacturing	0.095		
Chemicals manufacturing	26.229		
Basic metal manufacturing	12.916		
Mineral products manufacturing	58.749		

Paper products manufacturing	12.695		
Sugar refining	5.388		
Tea processing	1.872		

Appendix C: Average % change in real exports

Commodity		Initial	Sim0	Sim1	Sim2	Sim3
cpuls	row	0.35	2.77	-3.25	1.51	-0.52
coils	row	2.73	5.53	4.9	5.53	5.27
cvege	row	0.1	1.33	-2.77	0.5	-0.89
cfrui	row	0.08	5.85	0.54	5.35	3.38
cchat	row	0.97	-8.5	-21.14	-9.37	-14.65
ccoff	row	5.48	5.95	2.62	5.8	4.48
cflow	row	0.34	4.66	4.58	4.68	4.64
cocrp	row	0.56	-0.16	-8.68	-1.17	-4.45
ccatt	row	0.66	-7.03	-11.33	-7.37	-8.77
cmilk	row	0.02	-16.42	-24	-16.9	-19.56
cpoul	row	0.05	-3.27	-5.97	-3.54	-4.33
caprd	row	0.32	-1.32	-4.83	-1.55	-2.73
cfish	row	0.15	2.41	0.01	2.05	1.22
cdair	row	0.03	-16.35	-24.38	-16.78	-19.62
cgmll	row	0.66	18.93	14.05	20.64	17.59
cpsgr	row	0.07	30.16	9.79	30.82	24.16
cptea	row	0.06	1.23	-3.74	1.58	-0.89
cfood	row	0.16	-2.55	-7.68	-2.32	-4.86
cbeve	row	0.14	28.43	25.37	30.82	28.91
cptob	row	0.05	34.51	33.21	39	36.83
ctext	row	0.84	-0.17	-4.44	-0.2	-1.97
cclth	row	0.11	50.43	47.43	61.64	55.5
cleat	row	1.02	1.14	-10.79	1.57	-3.41
cwood	row	0.01	19.95	14.29	22.97	19.28

cpapr	row	0.35	31.54	35.09	39.35	37.62
cchem	row	0.5	29.19	21.95	28.98	26.05
cmetl	row	2.87	25.65	29.6	35.43	33.08
cvehe	row	0.4	14.5	18.2	19	18.73
ceequ	row	0.65	16.29	20.64	22.1	21.52
ctrad	row	1.15	14.01	15.89	17.15	16.65
chotl	row	1.51	9.95	11.03	9.98	10.53
ctran	row	19.08	25.95	27.42	30.48	29.2
ccomm	row	1.45	14.98	14.88	17.32	17.03
cfsrv	row	0.91	13.8	15.35	16.12	15.86
cbsrv	row	1.41	27.52	27.16	34.18	31.05
creal	row	0.37	13.05	12.73	13.13	13.03
cosrv	row	0.22	10.41	11.97	12.39	12.28

Appendix D: Average % change in real imports

		Initial	Sim0	Sim1	Sim2	Sim3
cwhea	row	6.65	16.88	25.55	17.89	21.32
cpuls	row	1.16	14.04	21.36	14.86	17.71
cteal	row	0	34.89	38.04	34.93	36.49
ctoba	row	0.13	23.39	25.01	26.03	25.62
cocrp	row	0.85	16.38	24.95	17.3	20.7
cpoul	row	0.02	16.58	21.59	16.66	18.7
cfish	row	0.01	12.28	15.9	12.07	13.8
ccoal	row	0.02	20.27	17.67	20.59	19.35
cngas	row	0.07	9.18	11.97	8.69	10.18
comin	row	1.86	11.22	18.41	17.95	18.2
cdair	row	0.44	32.2	44.82	32.77	37.51
cvprd	row	1.9	10.05	12.2	10.01	11.02
cgmll	row	0.28	3.13	7.65	2.29	4.79
cpsgr	row	0.8	21.33	23.92	22.25	22.96
cptea	row	0	16.76	23.26	16.51	19.71
cfood	row	1.43	14.89	20.4	14.74	17.4

cbeve	row	0.56	7.18	9.57	6.88	8.12
cptob	row	0.22	7.98	10.79	7.69	9.12
ctext	row	4.38	13.11	16.53	13.96	15.04
cclth	row	3.07	5.91	8.9	5.13	6.84
cleat	row	0.5	15.07	23.56	15.33	18.81
cwood	row	0.97	10.69	16.21	14.22	15.11
cpapr	row	2.27	9.12	11.09	10.49	10.76
cptrl	row	20.92	15.63	18.59	19.34	19.04
cfert	row	4.74	8.21	8	7.96	8.03
cchem	row	12.42	10.76	13.38	11.95	12.59
cnmet	row	5.27	9.72	17.11	15.73	16.34
cmetl	row	13.08	13.48	17.49	18	17.79
cmach	row	8.88	12.41	18.47	18.36	18.42
cvehe	row	8.78	11.52	15.69	15.15	15.4
ceequ	row	10.68	10.36	13.96	11.86	12.81
coman	row	1.66	5.99	9.85	5.86	7.57
ctrad	row	0.2	11.79	14.83	14.62	14.69
chotl	row	1.28	9.84	11.61	9.89	10.71
ctran	row	22.42	11.28	13.95	13.65	13.8
ccomm	row	0.97	9.7	12.94	10.82	11.58
cfsrv	row	1.23	9.74	13.08	11.63	12.27
cbsrv	row	5.09	11.89	14.28	14.39	14.34

Appendix E: Impact on real output of industrial and service sectors (percentage change)

Appendix E1: Impact on real output of industrial sector (percentage change)

	Initial	Sim0	Sim1	Sim2	Sim3	Sim1-Sim0	Sim2-Sim0	Sim3-Sim0
aomin	2.57	13.36	15.08	15.08	15.08	1.72	1.72	1.72
adair	12.05	5.32	5	5.26	5.36	-0.32	-0.06	0.04
avprd	0.02	8.24	9.26	8.23	8.69	1.02	-0.01	0.45
agmll	2.05	13.55	11.72	14.51	13.13	-1.83	0.96	-0.42
amsrv	2.32	15.56	18.78	16.57	17.62	3.22	1.01	2.06

apsgr	2.74	6.42	5.78	6.08	5.94	-0.64	-0.34	-0.48
aptea	0.41	7.78	8.53	7.76	8.11	0.75	-0.02	0.33
afood	6.66	5.81	5.79	5.82	5.81	-0.02	0.01	0
abeve	5.05	12.85	14.13	13.43	13.81	1.28	0.58	0.96
aptob	0.64	18.3	19.66	20.51	20.17	1.36	2.21	1.87
atext	4.6	5.12	4.43	5.42	4.99	-0.69	0.3	-0.13
aclth	1.17	27.44	27.54	33.56	30.79	0.1	6.12	3.35
aleat	2.69	5.42	1.48	5.72	3.99	-3.94	0.3	-1.43
awood	0.32	14.74	15.09	17.98	16.79	0.35	3.24	2.05
apapr	2.06	21.84	24.86	27.12	26.2	3.02	5.28	4.36
achem	3.15	20.31	17.69	20.63	19.38	-2.62	0.32	-0.93
anmet	2.29	16.37	15.56	17.24	16.57	-0.81	0.87	0.2
ametl	7.08	21.14	25.49	29.45	27.81	4.35	8.31	6.67
amach	0.03	13.57	19.04	19.35	19.26	5.47	5.78	5.69
avehe	0.81	13.72	17.55	18.02	17.87	3.83	4.3	4.15
aeequ	0.81	15.8	20.1	21.37	20.87	4.3	5.57	5.07
aoman	6.12	11.52	14.27	12.65	13.42	2.75	1.13	1.9

Appendix E2: Impacts on real output of service sectors (percentage change)

	Initial	Sim0	Sim1	Sim2	Sim3	Sim1-Sim0	Sim2-Sim0	Sim3-Sim0
aelec	3.58	14.65	16.91	15.58	16.25	2.26	0.93	1.6
awatr	3.92	11.59	13.65	12.97	13.56	2.06	1.38	1.97
acons	85.1	12.21	17.51	17.38	17.45	5.3	5.17	5.24
atrad	90.02	12.91	15.37	15.89	15.68	2.46	2.98	2.77
ahotl	40.9	9.9	11.31	9.93	10.62	1.41	0.03	0.72
atran	24.6	24.88	26.4	29.32	28.09	1.52	4.44	3.21
acomm	4.03	13.42	14.27	15.43	15.42	0.85	2.01	2
afsrv	10.5	11.96	14.32	14.08	14.23	2.36	2.12	2.27
absrv	1.41	27.52	27.16	34.18	31.05	-0.36	6.66	3.53
areal	37.01	11.61	12.98	12.15	12.56	1.37	0.54	0.95

aosrv	6.86	10.6	12.67	11.87	12.28	2.07	1.27	1.68
apadm	20.64	5.77	5.82	5.78	5.8	0.05	0.01	0.03
aeduc	11.08	6.29	7.08	6.8	6.93	0.79	0.51	0.64
aheal	3.23	6.81	7.75	7.34	7.54	0.94	0.53	0.73

Appendix F: Impacts on households' income

households	Initial	Share (%)	Sim0	Sim1	Sim2	Sim3
Highland cereal poor	29.51	8.3	9.89	10.26	9.72	9.99
Highland cereal non poor	109.91	30	9.78	10.86	10.81	10.85
Humid poor	15.67	4.4	10.33	11.07	10.95	11.00
Humid non poor	42.79	11.7	10.07	11.31	11.58	11.46
Drought prone poor	18.03	5.1	9.85	10.43	10.14	10.30
Drought prone non poor	41.01	11.2	9.83	10.99	11.07	11.05
Pastoral poor	3.78	1.1	9.98	10.94	10.03	10.44
Pastoral non poor	19.53	53.9	9.89	11.23	10.98	11.09
Farming poor	6.94	1.9	9.36	10.76	11.21	11.01
Non farming non poor	47.84	12	8.61	9.77	10.14	9.97
Urban poor	3.83	1	8.80	10.11	10.51	10.33
Urban non poor	35.54	8	7.65	8.67	9.05	8.88
Total	374.38	100	9.49	10.57	10.53	10.56

Source: simulation result

Appendix G: Household consumption expenditure

households	Initial	Share	Sim0	Sim1	Sim2	Sim3
Highland cereal poor	28.03	8.3%	9.63	10	8.61	9.28
Highland cereal non poor	101.66	30%	9.39	10.47	9.04	9.73
Humid poor	14.89	4.4%	10.08	10.81	9.83	10.29
Humid non poor	39.58	11.7%	9.67	10.92	9.8	10.34
Drought prone poor	17.13	5.1%	9.6	10.18	9.03	9.59
Drought prone non poor	37.93	11.2%	9.43	10.59	9.3	9.93
Pastoral poor	3.59	1.1%	9.73	10.68	8.92	9.73
Pastoral non poor	18.07	5.3%	9.49	10.83	9.22	9.97
Farming poor	6.54	1.9%	9.07	10.46	9.89	10.17
Non farming non poor	40.72	12%	7.89	9.04	7.75	8.38
Urban poor	3.43	1%	8.24	9.54	7.92	8.71
Urban non poor	27.04	8%	6.31	7.31	3.55	5.43
Total	338.61		9.05	10.1	8.58	9.31

Sources: simulation results

Appendix H: CGE Static Part "Within" Model

In this appendix the full formulation of the "within" or static CGE model and between (dynamic) is specified.

Sets, Parameters and Variables in the model

Sets

$\alpha \in A$ - 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 not in CD

$c \in CE(\subset C)$ - exported commodities

$c \in CEN(\subset C)$ - commodities not in CE

$c \in CM(\subset C)$ - imported commodities

$c \in CMN(\subset C)$ - commodities not in CM

$c \in CT(\subset C)$ - transactions service commodities

$c \in CX(\subset C)$ - commodities with domestic production

$f \in F$ - factors

$i \in INS$ - institutions (domestic and rest of the world)

$i \in INSD(\subset INS)$ - domestic institutions

$i \in INSDNG(\subset INSD)$ - domestic nongovernment institutions

$h \in H(\subset INSDNG)$ - households

Continued

Parameters (Latin Letters)

$cwts_c$ - weight of commodity c in the CPI

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

ica_{ca} - quantity of c as intermediate input per unit of activity a

$icd_{cc'}$ - quantity of commodity c as trade input per unit c' produced and sold domestically

$ice_{cc'}$ - quantity of commodity c as trade input per exported unit of c'

$icm_{cc'}$ - quantity of commodity c as trade input per imported unit of c'

$\text{int}\, a_a$ - quantity of aggregate intermediate input per activity unit

iva_a - quantity of value-added per activity unit

$\overline{mps_i}$ - base saving 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 price)

$qdst_c$ - 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 ($i' \in INSDNG'; i \in INSDNG$)

$\overline{tins_i}$ - exogenous direct tax rate for domestic institution i

$tins01_i$ - 0 - 1parameter 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

continued

Parameters (Greek Letters)

α^{va}_a - efficiency parameter in the CES value – added function

α^{ac}_{a} - shift parameter for domestic commodity aggregation function

α^{q}_{c} - Armington function shift parameter

α^{t}_{c} - CET function shift parameter

β^{h}_{ach} - marginal share of consumption spending on home commodity c from activity a for household h

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

δ^{ac}_{ac} - share parameter for domestic commodity aggregation function

δ^{q}_{c} - Armington function share parameter

δ^{t}_{c} - CET function share parameter

δ^{va}_{fa} - CES value –added function share parameter for factor f in activity a

γ^{m}_{ch} - subsistence consumption of marketed commodity c for household h

γ^{h}_{ach} - subsistence consumption of home commodity c from activity a for household h

θ_{ac} - yield of output c per unit of activity a

ρ^{va}_{a} - CES value – added function exponent

ρ^{ac}_{a} - domestic commodity aggregation function exponent

ρ^{q}_{c} - Armington function exponent

ρ^{t}_{c} - CET function exponent

Exogenous Variables

$\overline{CPI}$ - consumer price index

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

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

$\overline{GADJ}$ - government consumption adjustment factor

$\overline{IADJ}$ - investment 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

Endogenous Variables

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

DPI - producer price index for domestically marketed output

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_a - activity price (unit gross revenue)

PDD_c - demand price for commodity produced and sold domestically

PDS_c - supply price for commodity produced and sold domestically

PE_c - export price (domestic currency)

$PINTA_a$ - aggregate intermediate input price for activity a

PM_c - import price (domestic price)

PQ_c - composite commodity price

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

PX_c - aggregate producer price for commodity

$PXAC_{ac}$ - producer price of commodity c for activity a

QA_a - quantity (level) of activity

QD_c - quantity sold domestically of domestic output

QE_c - quantity of exports

QF_{fa} - quantity demanded of factor f from activity a

QG_c - government consumption demand for commodity

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

QHA_{ach} - quantity of household home consumption of commodity c from activity a for household h

$QINTA_a$ - quantity of aggregate intermediate input

$QINT_{ca}$ - quantity of commodity c as intermediate input to activity a

$QINV_c$ - quantity of investment demand for commodity

QM_c - quantity of import of commodity

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

QT_c - quantity of commodity demanded as trade input

QVA_a - quantity of (aggregate) value-added

QX_c - aggregated marketed quantity of domestic output of commodity

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

$TABS$ - total nominal absorption

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

$TRII_{ii'}$ - transfer from institution i' to i (both in the rest $INSDNG$)

WF_f - average price of factor f

YF_f - income of factor f

YG - government revenue

YI_i - income of domestic non-government institution

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

Model Equation

Price Block

[1] Import price

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

[2] Export price

$$PE_c = pwe_c.EXR - \sum_{c' \in CT} PQ_{c'}.ice_{c'c} \qquad c \in CE$$

[3] Demand price of domestic non-traded goods

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

[4] Absorption

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

[5] Marketed output value

$$PX_c.QX_c = PDS_c.QD_c + PE_c.QE_c \qquad c \in CX$$

[6] Activity price

$$PA_a = \sum_{c \in C} PXAC_{ac}.\theta_{ac} \qquad a \in A$$

[7] Aggregate intermediate input price

$$PINTA_a = \sum_{c \in C} PQ_c.ica_{ca} \qquad a \in A$$

[8] Activity revenue and costs

$$PA_a.QA_a = PVA_a.QVA_a + PINTA_a.QINTA_a \qquad a \in A$$

[9] Consumer price index

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

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

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

Production and Trade Block

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

$$QVA_a = iva_a . QA_a \qquad a \in ALEO$$

[12] Leontief technology: Demand for aggregate intermediate input

$$QINTA_a = \text{int}\, a_a . QA_a \qquad a \in ALEO$$

[13] Value-added and factor demands

$$QVA_a = \alpha^{va}{}_a \left(\sum_{f \in F} \delta^{va}{}_{fa} . QF_{fa}{}^{-\rho^{va}{}_a} \right)^{-\frac{1}{\rho^{va}{}_a}} \qquad a \in A$$

[14] Factor Demand

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

[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

$$QX_c = \alpha^{ac}{}_c . \left(\sum_{a \in A} \delta^{ac}{}_{ac} . QXAC_{ac}{}^{-\rho^{ac}{}_c} \right)^{-\frac{1}{\rho^{ac}{}_c - 1}} \qquad c \in CX$$

[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

$$QX_c = \alpha^t{}_c.(\delta^t{}_c.QE_c{}^{\rho^t{}_c} + (1-\delta^t{}_c).QD_c{}^{\rho^t{}_c})^{\frac{1}{\rho^t{}_c}} \qquad c \in (CE \cap CD)$$

[20] Export-domestic supply ratio

$$\frac{QE_c}{QD_c} = \left(\frac{PE_c}{PDS_c} . \frac{1-\delta^t{}_c}{\delta^t{}_c} \right)^{\frac{1}{\rho^t{}_c - 1}} \qquad c \in (CE \cap CD)$$

[21] Output transformation for non-exported commodities

$$QX_c = QD_c + QE_c \qquad c \in (CD \cap CEN) \cup (CE \cup CDN)$$

[22] Composite supply (Armington) function

$$QQ_c = \alpha^q{}_c.(\delta^q{}_c.QM_c{}^{-\rho^q} + (1-\delta^q{}_c).QD_c{}^{-\rho^q})^{-\frac{1}{\rho^q}} \qquad c \in (CM \cap CD)$$

[23] Import-domestic demand ratio

$$\frac{QM_c}{QD_c} = \left(\frac{PDD_c}{PM_c} . \frac{\delta^q{}_c}{1-\delta^q{}_c} \right)^{\frac{1}{1+\rho^q}} \qquad c \in (CM \cap CD)$$

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

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

[25] Demand for transaction service

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

Institutional Block

[26] Factor income

$$YF_f = \sum_{a \in A} WF_f.\overline{WFDIST}_{fa}.QF_{fa} \qquad f \in F$$

[27] Institutional factor incomes

$$YIF_{if} = shif_{if}.\left[YF_f - trnsfr_{rowf}.EXR\right] \qquad i \in INSD;\ f \in F$$

[28] Income of domestic, non-government institutions

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

[29] Intra-institutional transfers

$$TRII_{ii'} = shii_{ii'}.(1 - MPS_{i'}).(1 - TINS_{i'}).YI_{i'} \qquad i \in INSDNG;\ i' \in INSDNG'$$

[30] Household consumption expenditure

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

[31] Household consumption demand for marketed commodities

$$PQ_c.QH_{ch} = PQ_c.\gamma^m{}_{ch} + \beta^m{}_{ch}.\left(EH_h - \sum_{c' \in C} PQ_{c'}.\gamma^m{}_{c'h} - \sum_{a \in A}\sum_{c' \in C} PXAC_{ac'}.\gamma^h{}_{ac'h}\right) \quad c \in C;$$

$h \in H$

[32] Household consumption demand for home commodities

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

$a \in A; c \in C$

$h \in H$

[33] Investment demand

$$QINV_c = \overline{IADJ}.\overline{qinv_c} \qquad c \in CINV$$

[34] Government consumption demand

$$QG_c = \overline{GADJ}.\overline{qg_c} \qquad c \in C$$

[35] Government revenue

$$YG = \sum_{i \in INSDNG} TINS_i.YI_i + \sum_{c \in CM} tm_c.pwm_c.QM_c.EXR + \sum_{c \in C} tq_c.PQ_c.QQ_c$$

$$+ \sum_{f \in F} YIF_{govf} + trnsfr_{govrow}.EXR$$

[36] Government expenditure

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

System Constraint Block

[37] Factor market

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

[38] Composite commodity markets

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

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

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

[40] Government balance

$$YG = EG + GSAV$$

[41] Direct institutional tax rates

$$TINS_i = \overline{tins_i}.(1 + \overline{TINSADJ}.tins01_i) + \overline{DTINS}.tins01_i \qquad i \in INSDNG$$

[42] Institutional savings rates

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

[43] Saving-investment balance

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

[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

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

[46] Ratio of government consumption to absorption

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

Appendix I: The ''Between '' Model

[1] Average capital rental rate

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

[2]Share of New Capital

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

[3] Quantity of new capital by sector

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

[4] Unit price of capital

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

[5] Average capital rental rate

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

[6] Average capital rental rate

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

Declaration

I, the undersigned, declare that this thesis is my original work and has not been presented for a degree in any other university, and that all sources of materials used for the thesis have been duly acknowledged.

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