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Estimating the Economic Wide Effect of Ethiopian Renaissance Dam on Ethiopian Economy: A Recursive Dynamic Computable General Equilibrium Approach

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Abstract

This paper examines ***the economy wide effect of Ethiopian renaissance dam on Ethiopian economy.*** *The model is based on an updated Social Accounting Matrix for 2009/10 that takes into account the structural changes in the economy. Given the additional electricity generation capacity of Ethiopia, the model run a policy simulation in which the additional 6000MW that scheduled to come online near the future form renaissance dam. To analysis this policy option this paper outlined a recursive dynamic computable general equilibrium approach and hence uses the change in real GDP, sectors production, investment, external sector, household income and consumption expenditures, and household's welfare relative to the baseline, as an indicators of the economic wide effects of the renaissance dam. In opting for policy shock, the results of exercise showed that with an increment in power supply from renaissance dam the country can optimize the beneficial impacts on its economy. Specifically the simulation results show a spreading out effect in real GDP, sectors production, real investment, household income and household's consumption expenditure. Results also showed improvement in the welfare for all the household categories. However; the shift in relative income across the household categories favors high income households. Overall, this paper suggests that Ethiopian economy will enjoy the largest improvement with additional power supply resulting from Ethiopian renaissance dam, therefore; concerned bodies should exerted maximum efforts to finalize the projects on time and resolve the age-long problems of the people so that the economy maintains its tremendous progress.*

Keywords: *Computable general equilibrium, GAMS, electricity supply, Ethiopian Renaissance Dam*

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List of acronym

CES	Constant Elasticity of Substitution
CET	Constant Elasticity of Transformation
CGE	Computable General Equilibrium
CPI	Consumer Price Index
EV	Equivalent Variation
GAMS	General Algebraic Modeling System
GDP	Gross Domestic Product
GERD	Grand Ethiopian Renaissance Dam
GWh	Gig Watt per Hour
IFPRI	International Food and Policy Research Institute
IMF	International Monetary Fund
KWh	Kilowatt per Hour
MDG	Millennium Development Goals
MW	Megawatt
ROW	Rest of the World
SAM	Social Accounting Matrix
S-I	Saving – Investment
USD	United State Dollar

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Chapter one

1. Introduction

1.1. Background of the study

Conspicuously, now a day, electricity industry becomes a robust industry that enthusiastically contributes to the progress, prosperity and healthy development of the economy. In one hand, electricity has an exceptional ‘energy currency’ that underpins the economic development mode of the country (Coupal & Holland, 2002). On other hand, the level and speed of economic development also plays a decisive role in determining the demand for electricity in a given economy (Khandker et al., 2009). Therefore, when the economy has experienced in power failures, means that a lot of activity is forced to go on a standstill and, hence, directly thwart the fulfillment of the Millennium Development Goals by fading the society’s reaction to changes (Vera, 2016).

In Ethiopia, a severely restricted, inefficient and unreliable supply of electricity has historically recorded as a limiting factor for its economic development (Woldesenbet, 2005). More pronouncedly, the level of electricity production and consumption of Ethiopia become an important indicators and causal factors for its growth perspective. For instance; if we looked at the total electricity production and consumption of the country in 2010, it was 3.46 billion KWh and 3.13 billion KWh respectively. In 2014, Ethiopia’s total electricity production was 4.93 billion KWh; and the country’s final energy consumption was around 4.14 billion KWh, whereof 92 percent are consumed by domestic appliances, 4 percent by transport sector and 3 percent by industry. By then, the country’s real GDP had increased from USD 29.9 billion in 2010 to USD 55.5 billion in 2014. Three years later in July 2017, the country’s total electricity production was 9.5 billion KWh and its final electricity consumption was 6.7 billion KWh. In the same year its GDP was around USD78.4 billion (Index M undi, 2017). Therefore, from this evident one can ardently conclude that the economic development of the country depends heavily on electric supply mode of the economy.

Nonetheless, with its fast growth electrifying of million households, remote communities and small-scale entrepreneurs remains a challenge in Ethiopia; even if pleasingly Ethiopia has endowed with abundant water resources and enormous hydropower potential to put her out of this trap. Explicitly speaking, with an estimated theoretical hydropower capacity of 45,000 Mw, Ethiopia has the second highest hydropower potential in Africa after that of Democratic Republic of Congo (Kumagai, 2016), however; not for blessing till now Ethiopia has faced a myriad of energy problems. Symmetrically, it is also fact that the overall perfections in standard of living are manifested by the increment in sectoral outputs, the provision of efficient transportation, adequate shelter, healthcare and other human services. Yet these changes in services holistically requires universal electrification (Shiu and Lam, 2014), which in turn become a headache for Ethiopian government.

Consequently, after a wake up, in searching of options (i.e. to cover an imminent shortfall in electricity), Ethiopian government launched a plan to exploit the electricity generation potentials in the country. A major step in this regard was the notice in 2011 to construct the largest reservoir in Africa near the border to Sudan, the Grand Ethiopian Renaissance Dam with a storage capacity of 74 billion cubic meters and a power generating capacity of above 6000 Mw. In this milieu, the GERD is central to Ethiopia's development vision of becoming a middle-income country by 2025 and Africa's energy hub (Block and Strzepek, 2010). Moreover, by securing its energy supply, by providing electricity to a number of neighboring countries, and by making Ethiopia less dependent on oil imports, the GERD that presumably finalized in the coming years is supposed to support the economic development of Ethiopia.

Therefore, given the interdependence of economic activities, sensationally the impacts of GERD will infiltrate into all aspects of the economy through backward and forward linkages. In economic perspective, a significant shift in the power mix of an economy are bound to affect the structure of domestic prices across the whole economy with repercussions for the growth prospects of different production sectors and for the real income growth paths of different socioeconomic agents. Explicitly speaking, the construction of Ethiopian renaissance dam have direct impacts on individual sectors and then factor and product markets are likely to induce a chain of changes to the rest of the sectors in the economy. This in turn is expected to result in subsequent feedback effects. However, these and the like processes make its economic impact more complicated. Subsequently, economic wide evaluation is required with detailed information from a multiple perspective. In a nutshell, the aim of this paper is, therefore; to examine the economic wide impacts of Ethiopian renaissance dam on Ethiopian economy. To examine this policy option we specifically developed a recursive dynamic, multisectoral and general equilibrium model for Ethiopian economy by disaggregated the source of energy as energy from fossil fuel and hydropower.

1.2. Statement of the problem

Notwithstanding to these increment in public investments in energy sector, the current utilization of hydropower resources of the country are limited to 2,000 MW which is less than 5 percent of the estimated hydropower potentials of the country (Ferrari et al., 2013). Currently, only 27 percent of all households in Ethiopia have access to electricity and the remaining part of the population still relying on traditional biomass. Evidence has also shown that in Ethiopian economy a considerable power shortage was occurred in the years 1995/96, 1997/98, 1999/2000, 2002/03, 2008/09 and 2012/13, which was caused by disequilibrium in demand and supply of electricity coupled with sustained droughts. Certainly, these inadequate in supplies of electricity affect the healthy development of the economy.

On average, the electricity loss in Ethiopia is about 20 percent, which is much higher than the international average, 12-13 percent. For instance, as Woldesenbet (2005) have examined, power outages caused firms without backup generators to lose approximately 15 percent to 30 percent of their potential production. Even when the power shortages were less severe, losses could reach up to 10 percent. Their preliminary results also indicate that the economy may have lost 10 percent to 15 percent of total yearly gross value of production that could have contributed from the sector and 1 percent to 3 percent of total yearly government revenue because of power outages. That is why we said we all Ethiopians are badly needs the construction of this historic dam more than any other time and hence the maximum efforts need to be exerted to finalize the projects on time and resolve the yearlong problems of the people so that the economy maintains its tremendous progress.

Even if the renaissance dam has power to sustain and fuel Ethiopian economy from its tottered walk, the construction of the dam is not free from censure. The public debate on the construction of GERD has been characterized by the increasingly tone adopted by renaissance dam advocates and opponents. In one hand, the **pessimists** in their thought advised Ethiopian government to slow the construction of the GERD in order to evade the dam from absorbing most of its domestic finances. According to their narration, Ethiopian government has borrowed heavily from national banks to invest in the GERD and other large infrastructural projects, which could undermine the country’s macroeconomic stability as well, they remind that the dam will have a devastating environmental and social effect. In reaction to this criticism, the **advocate/ dam busters** enlighten that the construction of GERD has a long list of positive characteristics that explain its strong support and promotion over its negative effects. They would rather strengthen the speeches of Earl Eiker, chief of hydraulics at the U.S. Army Corps of Engineers:

"...if you're going to have sustainable development, you can't leave the environment totally pristine. This is a trade-off that we must accept, though impacts on the environment can and should be minimized. But without water resources development, this country wouldn't be what it is today. We all like to know that we will have water when we turn on the taps or lights when we flip the switch."

Hence, by accepting the rationales what the dam buster reminds, we intentionally recognize the renaissance dam as an important energy for eradicating poverty, changing unsustainable patterns of consumption and production, and sustainably developing the economy as stated in the Millennium Development Goals (MDG) since 2000. Given this inconclusiveness nature of the theme and debates on the construction of the dam in one hand and its dynamic infiltration impacts through backward and forward linkages to the economy in other hand, it is extremely important to investigate the economic wide effects of the project. This is especially important for a low-income country such as Ethiopia; where food deficit, balance of payments deficit and high imported fuel have dominates its economy.

In view of that, as the completion of the dam construction is getting closer and closer, more and more studies are being published and controversially discuss the likely consequences of the GERD on its environmental, social, economical, and political blueprints. However, the only other preliminary study that we know of is by Ferrari et al. and Tewodros et al., which tried to examine the economic wide effect of the dam. The study presented here employs a Computable General Equilibrium (CGE) modeling framework, but contrary to previous studies this study evaluates the direct and indirect economic effect of GERD on Ethiopian economy by employing a dynamic recursive multisectoral computable general equilibrium model via modeling the issue of electricity to a single-country approach.

At large, by filling the above knowledge gap, more specifically, this study attempts to answer the following research questions:

- What are the presumable effects of the GERD on household's income and consumption expenditure?
- What are the likely effects of the GERD on Ethiopian export and import volumes?

- What are the presumable effects of GERD on the sectoral productions and real investment?
- Will the construction of Ethiopian renaissance dam contribute toward its economic growth?

1.3. Objective of the study

1.3.1. General objective of the study

In line of the above research questions, the general objective of the study is to examine the economic wide effect of Ethiopian renaissance dam on Ethiopian economy by using a recursive dynamic computable general equilibrium model.

1.3.2. Specific objectives of the study

Apart from the above general objective, this paper has outlined the following specific objectives to evaluate the contribution that Ethiopian renaissance dam is expected to play on Ethiopian economy. These are:

- To examine the effect of Ethiopian renaissance dam on macroeconomic variables (i.e. external sector, investment, government spending, economic growth, and sectors production).
- To examine the likely effect of Ethiopian renaissance dam on microeconomic variables (i.e. households income, households consumption expenditure, factor income and household's welfare).

1.4. Significance of the study

The economy-wide nature of the CGE model that we have developed in this paper will gives us a detailed picture of the role which renaissance dam expected to play on Ethiopian economy over the coming years. More specifically, this research has a number of important benefits:

- The prior significance of the paper will lies on the Partial Fulfillment of the Requirements for the Degree of Masters of Science in Economics.
- Besides, the pathways derived from the analysis has in detail shows how the energy sector in Ethiopia may affect the economic phenomena over a long-term time horizon, and hence provide additional information that will helps energy policy makers to define guidelines and strategies for policies that shape the country's energy sector.
- Finally, it will also be used as a reference for further study and create an excellent pathway for other researchers to conduct further investigation on the area.

1.5. Scope of the Study

This study was focus on the economic wide effect of Ethiopian renaissance dam to Ethiopian economy by considering the years from 2010-2025. Here, the year 2025 is chosen as a maximum simulation period is because according to World Bank report the current economic growth of the country is lifting her from being the second poorest in the world to becoming a middle-income country by the year 2025.

1.6. Organization of the Study

The overall balance of paper is organized in five chapters. Chapter one discusses the introduction part of the paper which includes background of the study, statement of the problem, objectives of the study, significance of the study, and scope of the study. The second chapter has review both the theoretical and empirical literatures, which were conducted on the issue related with this area, coupled with a concisely depicted conceptual framework. Chapter three discusses the SAM and model specification that we have specifically developed to answer listed research questions. The fourth chapter has presents the simulation design and the results of simulations. The last chapter, chapter five, has presents the conclusion, policy recommendations and an indication of areas for further researches.

Chapter two

2. Literature review

2.1. Theoretical literature review

2.1.1. Definitions of terms

Energy is a well-known concept. Contradiction to free concepts, everybody has an understanding, and the majority has well-defined it. Different authors can define energy differently by using different word in a different environment. For instance, according to Merriam-Webster Dictionary in the context of chemistry, energy can be defined as an element of a substance that can be created as a result of its atomic and molecular configuration. In the context of biology, it can be defined as an attribute of all biological systems from the biosphere to the smallest living organism. In physics, “energy” can be defined as the ability of a physical system to do efforts. In economics, “energy” can be defined as all power resources or commodities, which can embody a significant amount of physical force to perform a given work or activities. For instance, gasoline, diesel, natural gas, propane, coal, or electricity might used to provide energy services for different work or activities.

Electricity can be defined as form of secondary energy source which have gotten from the conversion of other sources of energy (primary sources) like coal, natural gas, oil, nuclear power and other natural sources (IEA, 2017). Electricity by itself is neither non-renewable nor renewable but its sources can be non-renewable or renewable.

Hydropower is one of the cleanest, renewable and environmentally benign sources of energy (Renewable energy network, 2017). Its name is derived from two Greek words ‘Hydro’ and ‘Power’. ‘Hydro’ means water and ‘power’ means energy (IEA, 2017). All in one ‘hydropower’ is an energy that can be generated from water flows. According to the Merriam-Webster Dictionary, ‘Hydropower’ is electricity produced from machines that are run by moving water.

2.1.2. Potentials of hydropower in the world

Nowadays, world has witnessed with a sharp increment in global hydropower development, especially in the new millennium. In 2016, hydropower generated 17.6 percent of the world's total electricity and around 73 percent of all renewable electricity and was expected to increase about 3.3 percent each year for the next 25 years (World energy outlook, 2016). The technical potential for the growth of hydropower around the world are, 71 percent Europe, 75 percent North America, 79 percent South America, 95 percent Africa, 95 percent Middle East, 82 percent

Asia Pacific. However, globally, only few countries were dominated the domestic use and export of hydroelectricity generated from hydropower dams. Brazil, Canada, New Zealand, Norway, Paraguay, Austria, Switzerland, and Venezuela have a majority of the internal electric energy production from hydroelectric power. Paraguay produces 100 percent of its electricity from hydroelectric dams, and exports 90 percent of its production to Brazil and to Argentina. Norway produces 98–99 percent of its electricity from hydroelectric sources (Renewable energy network, 2017). The future largest increases in production volumes are expected in Brazil, the US, the EU, China, India, Indonesia and Malaysia (International energy agency report, 2014).

2.1.3. Theories of Energy and Economic Growth

<u>Basic principles:</u>

The basic principle of energy theories in production and economic growth is relies on the assumption of reproducibility. In the economics of production, some inputs of productions might be reproducible and some others might not be. For example, capital, labor and even natural resources in the long term are considered as reproducible factors of production but energy is accepted as a non-reproducible factor of production even if its part fuel is considered as a reproducible input of production (Stern, 1999). As a result, according to Hall et al. 2001 and 2003, ecological economists and natural scientists was attached a significant figure to energy inputs for its role which played in production and economic growth. More specifically, the premise of energy economics in production and economic growth banks on the idea that energy is necessary inputs for production and therefore growth. Therefore, according to Kardashev (1964), in the extreme cases, it is energy use rather than output of goods is used as an indicator for the state of economic development in a given country.

Now let us review the background theory of energy in production and growth from different points of view –those theories which based in economics and those theories which based in the natural sciences - in an attempt to assess to what degree of extent does energy availability enable and constrains economic growth.

2.1.3.1. Growth Models without Resources

When we make a close watch on the ideas of mainstream theory of economic growth, the role of energy on economic growth is not explicitly defined. Though there is nothing inherent in economics which restricts the potential role of energy, there is an inbuilt bias in mainstream production and growth theory to downplay the role of energy in the economy. Thus, to concretely understand the importance of energy in economic growth it is extremely important first to start with the role of energy in the production and then growth.

The basic model of economic growth is therefore, the Nobel Prize winning work by Robert Solow, which does not include resources at all. Therefore, the theories of production specifically the neoclassical economic theory try to explain the economy as a closed system where output is produced by factors of production (i.e. labor and capital). In this context, a change in economic growth is therefore; recorded because of an increment in inputs of production or the change in their quality. Consequently, in production processes energy inputs have got indirect importance and they have been considered as an intermediate input. However, according to Stern (1999), the concept of primary and intermediate factors of production has been accepted in the mainstream economists. In this thought, for instance, primary factors of production are those inputs that exist at the beginning of the period under consideration and are not directly used up in production even though they can be degraded (i.e. Capital, labor and land).

On the other hand, intermediate inputs are those inputs which have been created during the production period under consideration and used up entirely in production (i.e. fuels and materials). But as we have recall above and seen from different literatures, the mainstream theory of economic growth attached a primacy on the primary inputs, especially capital and labor, while those intermediate inputs like energy have got an indirect role in their discussions. More importantly; according to their narrations, even though the quantity of energy is determined by biophysical and economic constraints, the available of energy quantity in the economy is assumed to be endogenously given (Stern and Cleveland, 2004).

Hence, added to the neoclassical growth model, more recent there is dominant model known as endogenous growth theories, which attempt to explain the reasons for technological progress with economic choices and decisions taken by firms and individuals. The basic difference between the two thoughts were: while the neoclassical theory of growth is based on two "growth engines" -population growth and the traditional S-I-K accumulation mechanisms- the endogenous growth theory focuses on two growth mechanisms -capital investment and R&D. The first version in endogenous growth theory model were AK models, which got this name because they result in a production function of the form Y=AK, with A constant. However, in the newer version, capital input also includes human capital. According to them because of the technology spillover effects, the growth of human capital is not subject to declining return, as in Solow model.

The Neo-AK models were begun with Romer (1986, 1990). As, he pointed out in his discussion that even though at any instant knowledge is available as a free good to others; it become monopolized by discoverer to be more profitable. The other point presented a closely related approach to Romer is by Lucas (1988), via focusing on “social learning” and the trade-off between consumption and “human capital” development. The second Neo-AK model was followed by Schumpeter’s idea. This idea was primarily focused on active and a deliberate knowledge creation. Subsequently, Romer (1990), Grossman and Helpman (1990, 1991) and Aghion and Howitt (1992) created models where economic growth is based on research and development. Other models Acemoglu et.al (2006) tried to link the adoption of technologies to the role of institutions, Aghion et.al (2006) tried to link the adoption of technologies to financial markets and Holmes and Schmitz (2001) were tried to link the adoption of technologies to policies. At the end of the day, the important implication of endogenous growth theories is related to the role of policy measures like subsidies to R&D and investments in education that might be the key to long-term economic growth. In a nutshell, in an endogenous growth model, the economy can sustain a constant growth rate in which the diminishing returns to manufactured capital are exactly offset by the technological growth. Hence, the growth rate is permanently influenced by the savings rate (a higher savings rate increases the economic growth rate).

2.1.3.2. Growth Models with Natural Resources

Recently, some other studies analyze the role of resources with endogenous technological change. For instance, Ayres and van den Bergh (2005) have proposed a more disaggregated view on growth engines by offered a model of economic growth with energy resources and dematerialization. By doing so, they come up with a conclusion that, a sufficiently high growth rates requires resource input which is linearly increases with income. As well, Smulders and de Nooij (2003) come up with the point that apart from a possible on-time reduction in the level of energy use, there is a positive relationship between energy use and economic growth rate. This in turns implies that while the availability of investment capital has a significant impact on energy consumption and economic growth, the level of technology affects energy consumption as well. In the year 2001, conveniently Tahvonen and Salo have developed a growth model with renewable and non-renewable energy resources by including the costs of extraction in fossil fuels and costs of production in renewable energy resources. Their model were very realistically to explain the growth process for the economy as the use of fossil fuels rises in the beginning and then falls later as the economy is more developed.

More sensationally, energy resources and its prices have gained much more research attentions after the oil crises that have been occurred in the 1970s and 80s. Hereafter, energy resources and their prices become a hot issue for macroeconomic researchers and hence the healthy development of the economy was affected by a unit price change in oil market. Thus, according to the macroeconomic theory, due to higher costs in the short run an increase in energy prices will lead to an increase in the domestic price level and hence a decrease in output level. This situation in turns will decrease the aggregate demand and may lead firms forcefully to change or even cancel their investment plans, especially this is because of the fact that an increased in energy prices may result in higher interest rates.

Unsurprisingly in developing countries, it is state support and government commitment does heavily determine nation's access to energy and to economic development, and it is government's responsibility to establish a clear institutional framework and to decide the role of state owned companies, private national capital and international investors. According to Chevalier 2009, in developing countries it is the type of political governance, which determines the relationship between energy resources, energy policy and economic development. Therefore, institutional economists have done a better job by introducing the impact of economic, social and political institutions on efficient use of energy to understand the role of energy that have played in economic development (Paavola and Adger, 2005).

As a result, now a day, an alternative views on the relationship between economic growth and energy has appeared. In other saying, outside the mainstream growth theory there are much relevant literature that have been conducted on these issues which filled the interior pocket of growth models, for instance, ecological economics, which emphasized the importance of energy in production process and economic growth. In this block, by considering capital and labor as flows of capital consumption and labor services, rather than stocks, some of them even looked at energy as the only primary factor of production. Moreover, according to ecological economists, it is not just that energy is a crucial factor of production, but some (for instance Cleveland et al. 1984) even conclude that energy availability drives economic growth, and economic growth results an increased in energy demands.

Certainly, ecological economists consider an economy as an open subsystem of the global ecosystem and focus on the material basis of the economy. More technically, when we looked at the historical skeleton of the area, the laws of thermodynamics becomes common principles for various schools of thought that have been emerged so far. For instance, according to the first law of thermodynamics, energy cannot be created nor destroyed, only transformed. This means that the only available energy source is solar energy that can be used directly or in an embodied state such as fossil fuels. As well according to the second law of thermodynamics the entropy of an isolated system, which is not in equilibrium, will tend to increase over time. It implies that energy can be reused, but it will increasingly reach a less useful state and therefore additional energy is required.

In a nutshell, the role of energy in the growth process has examined in an extensive empirical work. When we figure out there principal findings, all are come up with a common tip that energy use per unit of economic output has declined. But this is due to a shift in energy use from direct use of fossil fuels to the use of higher quality fuels. When this shift in the composition of final energy use is accounted, energy use and the level of economic activity are found to remain tightly coupled. Furthermore, when we looked at time series analysis, we have seen that energy and GDP are co-integrated and energy use Granger causes GDP when additional variables such as energy prices are included. Symmetrically, when we take into account both theory and empirical results, the prospects for further large reductions in the energy intensity of economic activity seem limited. This has important implications for environmental quality and hence for economic policies.

2.2. Empirical literatures

As we move forward in the 21st century, undoubtedly we have found a number of literatures that controversial discuss the socioeconomic impacts of the construction of hydroelectric generating dams. When we make a cloth watch on those literatures, however; few studies were conducted to assess the issue and quantify its impacts on economic growth and poverty reduction. One reason for this, according to World Energy Outlook (2017), is that it is quite challenging to quantify the benefits of hydroelectricity compared to other sources of energy because this calls for assigning prices to different effects such as climate benefits, air quality, human health, and sustainability of energy source. Besides, as Ghosh (2009) points out, one of the reasons why there is little understanding on the links between hydroelectricity supplies and poverty reduction is the fact that the relationship between them consists of several steps, and then many factors were influenced each of these steps. At the upshot, there are scant literatures available on the economic effect of hydroelectricity generating dams, and for the sake of current review we can classify those literatures into two broad clusters as: macro and micro - level literatures. Hereafter the macro – level researches can further be divided in to two, based on the methodological framework what they employed, as those literatures conducted on computable general equilibrium model and those literatures examined by econometric modeling with time series and panel specification.

In the first line of research we try to review literatures which attempt to examine the impact of hydroelectricity generating dams only on macroeconomic variables by employed a computable general equilibrium modeling framework (For instance: Bohlmann, et al., 2015; Levent, 2010; Robinson & Gueneau, 2014; Kenneth et al., 2007; Tewodros et al., 2015 and Ferrari et al., 2013). Bohlmann et al. (2015) in their paper to examine the economy-wide contribution that the additional electricity generation capacity from Kusile and Medupi will bring to the South African economy, argued that in terms of the new power generation capacity the macroeconomic impact of Kusile and Medupi power stations were a definite positive. Specifically their results show that, in the medium term, investment expenditure was particularly sensitive to the building of these new power plants. Additional costly blackouts are also likely to be avoided, and hence promoting a further economic growth and investment. Thus, once Kusile and Medupi are fully operational and able to provide its projected 9600MW of base load electricity supply, old coal-fired power plants may be decommissioned and replaced by cleaner and more efficient generation sources as outlined in the Department of Energy's Integrated Resource Plan. Lastly, the outcome of the paper in their analysis also suggests that the construction of these two power stations become a good balance between utilizing modern clean coal technologies that are cost-effective while laying the foundation to improving our generation-mix and carbon emissions profile.

Levent (2010), tried to analyze the potential long term impacts of the hydropower expanding shock on some macroeconomic variables of interest such as GDP, real consumption, real investment, exports, imports, trade balance, and carbon emissions, by developed a dynamic multi-sectoral general equilibrium model of the Turkish economy. His simulation results show that doubling hydropower have slightly positive effects on macroeconomic indicators and carbon emissions for Turkish economy. More specifically, doubling of hydropower in Turkish yields a real GDP, real consumption, real investment annually increase by 0.14, 0.13, and 0.07 percent respectively in the period of 2010-2020. While exports increase by 0.31 percent, imports also increase by 0.19 percent in the same period. Moreover, in his paper he showed that since government expenditure is assumed to remain at its control scenario level that is constant, the deterioration in the terms of trade what he found is absorbed mostly by the Turkish households i.e. 0.09 percent. Besides, at sectoral level his simulation result also shows that expanding hydropower plants have a negative effect on agriculture (by 0.04 percent), since electricity are also intermediate inputs used by other industries, causing considerable indirect real output rise in the fossil fired electricity (by 0.15 percent), oil product industries (by 0.06 percent). Other industries getting particularly affected are gas (by 0.3 percent) and coal (by 0.18 percent) and other industries and services (by 0.03 percent). On the environment side the impact of expanding hydro power on the CO_2 emissions is found to be positive but it is not so significant. The carbon emissions is on average 0.012 percent lower than the base case over the ten-year simulation period while expanding hydro power generation are assumed to be doubled.

Kenneth et al. (2007), in their paper to examine the economic impact of the High Aswan Dam to Egypt's economy by using a computable general equilibrium model they indicate that steady water supply sustained by the High Aswan Dam is increased the productivity of transport sectors. As well, they showed that year round availability of predictable and adequate water was sustained a shift towards more valuable summer crops. These static effects are worth EGP 4.9 billion. By comparing the actual 1997 economy to the 1997 economy as it would have been if historical pre-dam Nile flows (drawn from a 72-year portrait) had applied (i.e., the Dam had not been built) they also argued that investments in transport and agriculture sector is increased. As a consequence; these investments, assuming that Egypt is a small open economy, added another EGP 1.1 billion to the value of the Dam. They also estimate the risk premium on the reduced variability, and found that for a modest risk aversion it is estimated to be EGP 1.1 billion, and for a high risk aversion the risk premium perhaps is EGP 4.4 billion. Therefore, they conclude that the total gain of is EGP 7.1 billion to 10.3 EGP billion which equals 2.7 percent to 4.0 percent of the annual GDP of Egypt in 1997.

Robinson & Gueneau (2013) in their study to estimate the potential economic wide effect of building the Diamer-Basha dam to Pakistan economy using integrated system of economic and water simulation model with different climatic scenarios point out that the construction of the dam would improve the resilience of Pakistan to adapt to climate shock, provides increase hydropower capacity and enhancing the ability to manage the water system to offset climate induced variations in river flows. They also argued that given the modest amount of existing water storage capacity in the Indus river basin the extreme events like an extended drought overwhelms the water management system and the proposed dam partly offset the negative impacts which arise from the construction of the dam. Lastly according to their finding the construction of the dam is an excellent investment under different climate scenarios, it yields a benefit cost ratio of 3.3 to 3.9 and an internal rate of return 11percent to 14 percent.

The paper of Ferrari et al. (2013) and Tewodros et al. (2015) were appeared to be the only research work that quantitatively estimated the direct and indirect economic impacts of the Grand Ethiopian Renaissance Dam (GERD) on the Eastern Nile economies by employed a multi-region multi-sector computable general equilibrium (CGE) modeling framework. The first study employed a dynamic version of the GOBE_ENCGE model to assess the possible economic effects of the GERD on the Eastern Nile economy by extended the electricity generating sector between hydro and fossil fuel powered electricity in Ethiopia, Egypt and Rest of Eastern Africa (that includes Sudan). Their preliminary results indicate that the investment in the GERD would slow down development level in Ethiopia and for the investment to be profitable exports of hydroelectricity need to expand rapidly after completion of the dam. They also argued that an increase in the Ethiopian export of electricity could lead to "Dutch disease". The second paper employed a multi-region multi-sector computable general equilibrium (CGE) modeling framework, to estimate the direct and indirect economic impacts of the Grand Ethiopian Renaissance Dam (GERD) on the Eastern Nile economies. Their preliminary results demonstrate the significance of the GERD in generating basin wide economic benefits and improving welfare in the Eastern Nile basin. Specifically, during the impounding phase the GERD benefits mainly Ethiopia and to some extent Sudan. They also narrated that GERD impounding inflicts economic costs, however, on Egypt, especially if it occurs during a sequence of dry years, and depending on the level of water withdrawal in Sudan. Thus, the negative effects of the GERD on Egypt's economy will reversed when the GERD becomes operational. Moreover, their findings also disclose that Egypt's economy is constrained more by energy than water, i.e., Egypt's economy is more sensitive to changes in energy supply than water supply. Therefore, instituting a basin wide power trade scheme whereby Ethiopia exports part of the enormous amount of new hydropower generated from GERD to Egypt would substantially boost Egypt's economy and thereby increase the basin-wide economic value of the dam.

Now let me tag on my narration on literatures in the same cluster but which attempt to analyze the effect of hydroelectricity consumption on economic variables by employing time series econometric modeling. Different authors have used different methodologies, countries and periods to explain the relationship which has been existed in economic growth and hydro electric consumption. Accordingly, in the theory of energy consumption and economic growth, literatures have suggested four hypotheses and hence, our reviews in this sub-cluster has based on these hypothesis. The first is neutrality hypothesis which states that there is no causal link existed between energy consumption and economic growth. In explicitly speaking, according to this hypothesis an increase/decrease in energy consumption will not affect economic growth and vice-versa. The second one is conservation hypothesis which explicitly states a unidirectional causal link exists from economic growth to energy consumption. Pronouncedly, according to this hypothesis only a change in economic growth will lead to a change in energy consumption, not vice-versa. The third hypothesis is growth hypothesis which assumes a unidirectional causal link existed from energy consumption to economic growth. In this hypothesis only changes in energy consumption will have impact on economic growth. The last hypothesis is feedback hypothesis which assumes bidirectional causal links existed between energy consumption and economic growth. According to this hypothesis changes in energy consumption will have an effect on economic growth at the same time changes in economic growth will also impact the demand for energy.

For instance, Mahirah (2010) in his study tried to investigate the nexus between hydroelectricity and gross domestic product in Malaysia during the period of 1975-2008 and pointed out that hydroelectric consumption and GDP are co integrated in the long term and there is a unidirectional causality running from economic growth to hydroelectric consumption. According to him this may implies that energy policies might be implemented with little adverse or no effect on economic growth. Atif & Siddiqi (2010) tried to examine the link between electricity consumption and GDP in Pakistan between 1971 and 2007. The results of the study suggest that an increase in the use of electricity in Pakistan leads to an increase in economic growth. The paper also suggests that the slowdown in electricity consumption within the country has hindered economic growth. Growth in energy consumption fell from 7.6 percent in 2006/2007 to 0.9

percent in 2007/2008, and the paper also suggests this slowdown has leads to a decrease in GDP growth from 6.7 percent in 2006/2007 to 4.1 percent in 2007/2008.

Koengkan (2017) has also tried to analyze the nexus of hydroelectricity consumption and economic growth in seven Latin American countries in the period from 1966 to 2015, using an auto-regressive distributive lag (ARDL) methodology. The study results suggest the existence of feedback hypothesis in short-run where the hydroelectricity consumption and economic growth are interrelated. In the same fashion, Adebola (2011) tried to investigate the relationship between electricity consumption and real GDP in Botswana from 1980 to 2008. This paper tries to test a model where economic growth is a function of capital, labor and electricity. The result of the paper suggests that long-term increases in energy consumption are associated with increases in real GDP. The exercise also finds that capital formation has an impact on real GDP. Since the economy of Botswana is highly dependent on energy, the paper speculates that the ability of capital to positively influence economic growth is partly determined by the availability of adequate energy within the country. At the same fashion, Ocal and Aslan (2013) tried to examine the renewable energy consumption and economic growth causality nexus in Turkey, for the period 1990-2010 and found that the existence of a unidirectional causality running from economic growth to renewable energy consumption.

Al-Mulali et al. (2013) analysis their study on 108 low and high income countries, from the period for 1980-2009, and they pointed out that in 79 percent of the countries there is the existence of feedback hypothesis, in 19 percent of the countries they found the existence of neutrality hypothesis and in 2percent of the countries they found that the existence of conservation and growth hypothesis. Bayat *et al*. (2011) have tried look at the relationship between electricity consumption and employment within the manufacturing sector in Turkey between 1960 and 2005. The findings of the study suggest that GNP has an impact on electricity consumption; it also finds that there is no relationship between electricity consumption and employment in the manufacturing sector.

Polat & Uslu (2012) also examine the link between energy consumption and employment in Turkey from 2005 to 2010. Unlike the Bayat *et al.* (2011) study, the authors find that electricity consumption does have an impact on employment. A similar study by Shahbaz & Dube (2012) on coal consumption in Pakistan between 1972 and 2009 finds that whilst coal consumption, capital use and labor participation have a positive effect on economic growth, there is no direct relationship between coal consumption and employment. Odihambo (2010) has also tried to examine the relationship between energy consumption, energy prices and economic growth in South Africa, Kenya and the Democratic Republic of Congo (DRC) between the year 1972 and 2006. The finding of the study suggests that an increase in energy consumption leads to economic growth in South Africa and Kenya whilst economic growth leads to an increase in energy consumption in the DRC. His exercise also finds that in Kenya, energy prices influence economic growth whilst in the DRC, energy use influences energy prices. As well Bildirici (2016) analyze the relationship between economic growth and hydropower energy consumption in Brazil, Finland, France, Mexico, the U.S., and Turkey from 1980 to 2011 pointed out the existence of conservation hypothesis in the analysis.

The only contrary result has been observed in Adom (2011) study which tried to assess the link between electricity consumption and economic growth in Ghana between 1971 and 2008. The findings of the study states that Ghana's most productive sectors – agriculture and services – are not energy intensive, and the industrial sector – which theoretically links electrical consumption to economic growth – has been in decline. As a result, electricity consumption has not been a driver of economic growth, and instead economic growth has led to greater electricity consumption.

The Second line of research included those studies that have been conducted on the effect of hydroelectricity consumption on the micro economic variables specifically on households and firm's income, factor income, employment, and firm's productivity. In economic literatures the impacts of electricity on the micro-level are often examined using the same indicators as on the macro-level, the main difference lies in the level of aggregation. Table 2.1 below summarizes micro – level literatures which tried to examine the effect of electricity on the micro economic variables in a more intriguing way.

Authors	*Sampled countries*	*Sample size / sources of data / sampling units*	*Conclusions*
Grogan, 2008	Guatemala	At community level 485 communities, household level data and LSMS individual	There is a Positive effect of electrification on women's labor force participation & men's and women probability of being engaged in more skilled labor after at least ten years
UNDP, 2011	Nepal	Household survey conducted in communities with and without access to electricity from micro hydropower schemes	Significantly, a higher income in villages served by micro hydropower schemes was found; electricity access explains about 30 percent of the increase.
ESMAP, 2005	Tanzania	Enterprise survey of 320 connected and non-connected SMEs; focus groups	90 percent of connected SMEs stated that their business income increased since electrification and 85 percent of them stated that this can be attributed to the use of electricity. 80 percent of focus group discussants stated that the volume of their business and the number of clients had grown.
Bernard et al., 2009	Ethiopia	Survey of 800 households	They found that no significant effect of electrification on changes in household expenditure
Fan et al., 2005	Tanzania	Household Budget Survey (HBS) of approx. 22,000 households	1 percent increase in the electrification rate would lift approx. 140,000 people out of poverty.
ESMAP, 2002	Philippines	Survey of approx. 28,000 domestic, commercial, industrial and irrigation units with and without electricity	Average incomes of home businesses using electricity are significantly higher than those who do not use electricity but no positive impact of electrification on incomes from agriculture was found.
Hill and Kalijaran, 1993	Indonesia	2,250 small clothes producers	They found that a Significant positive effect of energy consumption on technical efficiency

Table2.1*: Summery of literatures on the effect of electric consumption on microeconomic variables*

In a nutshell, two main conclusions can be drawn from the existing literature on the future energy and economic growth nexuses in Ethiopia. First, energy use is either the cause or the facilitator of economic growth. Second, economic growth and energy demand are linked, but the strength of that link varies among regions and their stages of economic development.

2.2.1. Comparison of studies conducted on Ethiopian renaissance dam

Despite the importance of the subject, there exists only limited literature examining the economic-wide impacts of Ethiopian renaissance dam. Now we are in the position to compare and contrast those literatures which have been conducted on Ethiopian, specifically on renaissance dam, for the sake of searching a research gap for the study under consideration. In a convenient way when we compare the results of Tewodros et al. (2015) and Ferrari et al. (2012), we can glimpse a conflicting result even if both papers employed computable general equilibrium model and conducted in the same country. This might be the fact that, firstly; the study by Tewodros et al., (2015) was conducted approximately 3 years later than the one of Ferrari et al., (2012), secondly; the first study evaluated the impact of the dam under three different climatic and hydrological scenarios while the other is not, and thirdly; the first paper taking into account both the transient of GERD impounding phase and the long-term operation phase in a global CGE setting while the second doesn't. Accordingly, the results of the first study demonstrate the significance of the GERD in generating basin- wide economic benefits and improving welfare in the Eastern Nile basin. However, the results in the second paper point out that the investment in the GERD would slow down development level in Ethiopia and an increase in the Ethiopian export of electricity could lead to "Dutch disease".

Consequently, given the inconclusiveness of the research and debates on the construction of Ethiopian renaissance dam in one hand and the conflicting pattern that we have observed in the analyses conducted by Ferrari et al., (2012) and Tewodros et al., (2015) to estimate the economic wide effect of GERD in another hand, it is extremely important to investigate whether this result would change if we model the issue of hydropower to a single-country approach and if we employed a dynamic recursive multisectoral version of the CGE model to Ethiopian economy.

2.3. Economy wide Conceptual Framework

Technically in general equilibrium analysis, computable general equilibrium (CGE) model provides a consistent framework to analyze the economic wide impacts of energy and environmental policy. Since it has sound micro-economic foundations and have completely describe the economy with both direct and indirect effects for a policy change, now a day CGE models became the mainstream of energy and environmental policy analysis.

In such circumstance economic growth and energy policies are linked with backward and forward linkages which resulting from factor and product market interaction. Evidently, this backward and forward linkage is at the end of the day determining the overall state of the economy. The direct effect of Ethiopian renaissance dam is increasing electricity production level in the economy. Pronouncedly, if we account this direct effect (i.e. increasing the supply of inputs to downstream industries), the forward linkages are immediately arising in production. Explicitly speaking, when the supply of electricity expands with the construction of Ethiopian renaissance dam, it can provides more services to producers, enterprises and other processors which again raises production and productivity of the remaining productive sectors. Subsequently, in our model the backward linkages are also arising in production when productive sectors demand more intermediate inputs such as electricity. Henceforth, the more the electricity intensive a sector is the stronger the backward linkages are in the model.

Symmetrically, in our model consumption linkages also arises when household incomes are used to buy different good and services. For instance, when supply of electricity expands through the construction of the dam, it obviously raises households and enterprises income, which are then used to purchase different good and services for the sake of their consumption. However, here the size of consumption linkages are depends on the share of factor income distributed to households, the composition of the consumption basket, and the share of domestically supplied goods in consumer demand. Furthermore, changes in output generated by the dam may affect prices of direct project outputs, inputs, its substitutes, its complements and other factors of production. Here, changes in wages and prices have both income and substitution effects on the expenditure and saving decisions of different owners of factors, which further impacts the demand for outputs within the region and throughout the economy. As well induced impacts reflect the feedbacks associated with these incomes and expenditure effects, and also include any impacts of changes in government revenues and expenditures that result from the dam construction.

Added to this, our CGE model also covers the public sector. Here, the role of government is to levies and collects direct and indirect taxes. Hereafter, it uses these revenues to pay for recurrent consumption spending, which in turn generates demand for producers' goods and services. The government also pays for social grants and makes capital investments in one hand and receives financial assistance from abroad through borrowing or foreign aid in other hand. Besides, in our model foreign markets are also a source of export demand and a supplier of imports. Here, the size of growth multiplier effects is determined by the combined export-intensity and import-penetration ratios of individual sectors. A country with high export intensity faces less stringent domestic demand constraints, whereas a higher import penetration ratio means greater competition from foreign producers.

Furthermore, since our CGE model is recursively dynamic, savings are collected into a national pool and are used to finance various investment activities. Then, to determine the rate of capital accumulation these investments are converted into capital stocks. Henceforth, the changes in factor supplies and productivity through investment determine the overall rate of economic growth in the country.

In a nutshell, the immediate impact of the construction of Ethiopian renaissance dam is a significant expansion in output of electricity sector itself. This output expansion in electricity therefore; results in a higher demand for intermediate inputs thereby creating a spillover effect to the rest of the economy (i.e. as other sectors also increase their production to meet higher demand of their products). As a result, employment and returns to factors of production increases as well. Consequently, this higher in return to factors creates a snowball effect, as greater profitability in the electric sectors attract further investments and consumption. This is true especially for the sectors which have the strongest forward linkages with electricity (i.e. manufacturing, industry, and service sectors). At the end of the day, the rise in investment changes the production and productivity of economic activities, which in turns determine the overall state of the economy indicating that GDP is rising.

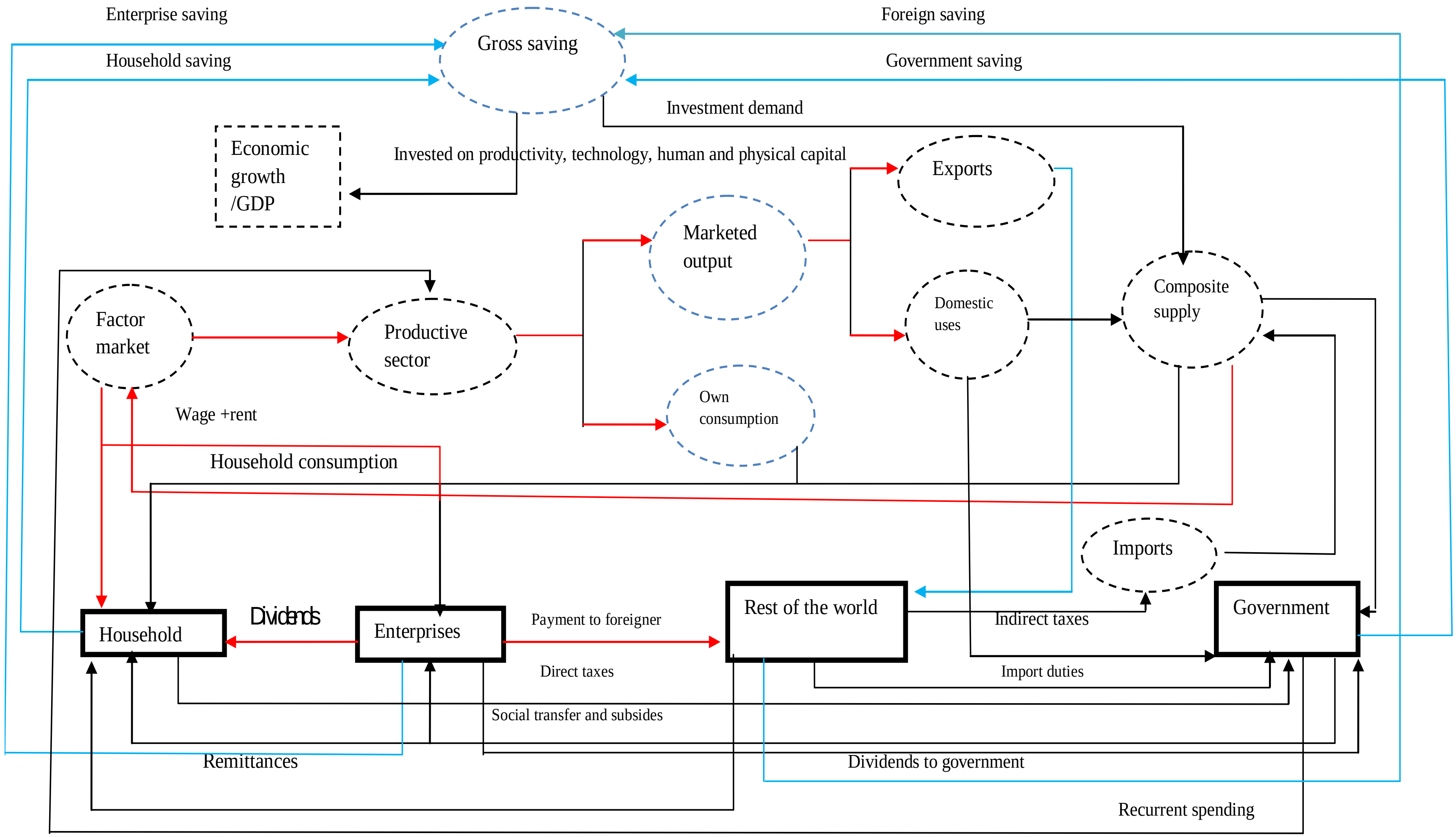

Figure2.1: *Economic wide conceptual framework for Ethiopian economy (*adapted from Benfica et al. (2006)*)*

Chapter three

3. Methodology

3.1. Source of Data

To capture the economic wide effect of Ethiopian renaissance dam to Ethiopian economy, this study employed a dynamic CGE model by utilized 2009/10 SAM of Ethiopia which represents the economy by activities, factors, commodities, and institutions including an aggregate savings-investment account. Therefore, the source of data for this study was 2009/10 SAM of Ethiopia which we have obtained from EDRI. The SAM required aggregation and disaggregation work to fit needs of the study and the modeling requirements. In addition, the SAM has been updated for the year 2016/17 to reflect the extent of possible macroeconomic situation during that period without changing 2009/10 economic structures (i.e. by recalibrating model parameters).[1] The value of the average GDP growth rate from 2009/10 to 2016/17 was taken as a reference. The following were also taken as benchmarks to recalibrate the SAM using their average shares from 2009/10 to 2016/17 GDP: Agricultural GDP: 40%, Manufacturing GDP: 15% and services GDP: 45%. In this study, data from Ethiopia electric power corporation was also employed to disaggregate the energy sources and develop a simulation design.

3.2. Description of the study area

The ultimate site for the Grand Ethiopian Renaissance Dam was identified by the United States Bureau of Reclamation during a Blue Nile survey conducted between 1956 and 1964 as well Ethiopian Government surveyed the site in October 2009 and August 2010. Finally, in November 2010 a design for the dam was submitted (Ethiopian Water and Technology minister report, 2013). Grand Ethiopian Renaissance Dam (formerly known as the Millennium Dam and sometimes referred to as Hidase Dam), is a gravity dam on the Blue Nile River in Ethiopia that has been under construction since 2011. It is located in Benishangul-Gumuz Region of Ethiopia, on the Blue Nile about 20 Km away from the Ethiopian Sudanese Border and will built totally by local engineers and technicians (News one, 2011).

[1] In this model parameters have been calibrated based on the prevailing economy structure by considering empirical literatures, and economic reports. For instance, in our recalibration process the growth of cultivated land set to 2.7% on average between 2009/10 and 2016/17, labor force growth on average set to 3 percent from 2009/10 to 2016/17 and the residual TFP of the model set to grow on average by 6 percent.

According to international panel of experts, the main body of the dam is Roller Compacted Concrete (RCC). The Dam is currently under construction; where about 65 percent of the project is completed. The Dam is anticipated to operate within the next year, by 2018, with a height of 145 meters above the foundation level, and a crest length is 1780 meter. The reservoir area will cover 1874 square Kilometer at full supply level of 640 meters above sea level. The expected average energy production is 15,692 GWh per year. A 500kV switchyard will also be constructed to transmit power from the power stations to the grid (International Panel of Experts, 2017). Regarding to the contract, Alstom signed a €250m contract with Metals & Engineering Corporation (METEC) to supply turbines, generators and all electromechanical equipment for the hydropower plant of the Grand Renaissance Dam. The cost of the project is estimated to be 47 billon US dollars; where about two-thirds of that is going to civil workers and one third for equipment. The owner of project is the Ethiopian electric power corporation (International Panel of Experts, 2017). The Figure below shows the current status of Ethiopian renaissance dam.

Figure3.1: *Current status of Ethiopian renaissance dam.*

Source: http://www.dw.deegypt-and-ethiopia-argue-over-dam-projecta-16880722

3.3. Social accounting matrix

In a narrower sense, a social accounting matrix (SAM) represents flows of all economic transactions that take place within an economy. It is at the core, a matrix representation of the national accounts for a given country, which provides a static picture of the economy (Pyatt and Thorbecke, 1976). As a data framework, the SAM is a snapshot, which explicitly incorporates various crucial transaction links among variables, such as the mapping of factorial income distribution from the structure of production and the mapping of the household income distribution from the factorial income distribution, among others. In other saying, it is a comprehensive accounting framework within which the full circular flow of income from production to factor incomes, household income to household consumption, and back to production is captured.

In a broader sense, in addition to providing a consistent classification scheme, it can conceive as a modular analytical framework for a set of interconnected a subsystem, which specifies the major relationships among variables within and among these systems (Luppino et al., 2004). 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, SAM may have extra accounts like taxes, total margins (EDRI, 2010). Now let us elucidate each account more explicitly.

***Activities and commodities**:* EDRI SAMs distinguish between "activities" (entities that carry out production) and "commodities" (representing markets for goods and non-factor services). SAM flows are valued at producer prices in activity accounts and at market prices in commodity accounts, i.e., inclusive of indirect taxes and transactions cost margins. Commodities consist of activity outputs, either exported or sold domestically, and imports. In the activity columns, payments are made to commodities (intermediate demand) and factors of production (value-added, equal to operating surplus and compensation of employees). In the commodity columns, payments are made to domestic activities, the rest of the world, and various tax accounts (for domestic and import taxes).

***Government income and payments**:* The government in EDRI SAM is disaggregated into a core government account and various tax collection accounts. Tax accounts are necessary since otherwise the economic interpretation of certain payments becomes ambiguous. Direct payments between the government and other domestic institutions are reserved for transfers. Payments from the government to factors are captured in the government services activity. Government consumption demand is a purchase of the output from the government services activity, which in turn, pays labor.

***Domestic non-government institutions**:* Domestic non-government institutions consist of households and enterprises. Enterprises earn factor incomes (reflecting their ownership of capital) and receive transfers from other institutions. Enterprise incomes are used for corporate taxes, enterprise savings, and transfers to other institutions. Unlike households, enterprises do not demand commodities. In the SAM, enterprises are an aggregation of financial and nonfinancial corporations, as defined within the System of National Accounts (SNA).

Household consumption: EDRI SAMs distinguish between home (own) consumption of activities and marketed consumption of commodities by households. Home consumption, which appears in the SAM, as payments from household accounts to activity accounts, is valued at producer prices, i.e., without marketing margins and sales taxes that may be levied on marketed commodities. Final household consumption of marketed commodities appears as payments from household accounts to commodity accounts, valued at consumer prices including marketing margins and taxes.

Saving and investment: savings-investment (S-I) account in the standard EDRI SAM represents the "loanable funds" market. This 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. In this context the undated 2009/10 SAM of Ethiopia captures:

- The sources of income and expenditure destination of all accounts,
- Breakdown of sectoral GDP (value addition) by labor and capital factors,
- Income generation and distribution of the institutions in general and household groups in particular,
- Patterns of expenditure by institutions including Household groups,
- The inter-dependence between activities and institutions with respect to income generation and final demand creation,
- The inter-dependence among institutions regarding transfer receipts and transfer payments,
- The role of institutions in capital formation, and
- The relationship of the domestic economy with the Rest of the World / external sector.

3.4. Model formulation

This paper attempts to examine the economy-wide effects of Ethiopian renaissance dam to Ethiopian economy using a recursive dynamic computable general equilibrium (CGE) model.

This is because CGE models have features that make them suitable for such analysis (Janda et al., 2011), as it has sound micro-economic foundations and a complete description of the economy with both direct and indirect effects of a policy changes. More explicitly, in the CGE model the general equilibrium theories are transformed from an abstract form into a realistic and computable one by using a set of equations to characterize supply, demand and equilibrium conditions in the economic system. Therefore, in these equations there are both economic shocks or exogenous variables and endogenous variables or quantities and prices. Consequently, the impacts of exogenous economic shocks on any sector will spread to the whole system of the economy, which in turns lead to the changes in those endogenous variables. Therefore, the state of equilibrium changes from one point to another. Here, by solving the CGE model we can be obtained a new equilibrium quantities and prices whenever the exogenous variables are changed. The unique advantage of the CGE approach over partial equilibrium approaches is its ability to incorporate these 'ripple effects' in a systematic manner.

Moreover, literatures in general equilibrium theory broadly classify CGE models in to two as: static and dynamic. A static CGE model shows a onetime effect of policy changes in a given economy. Thus, static CGE models are unable to account for second round effects. In such a model, the process of adjustment to the new equilibrium is not explicitly represented, although details of the closure lead modelers to distinguish between short-run and long-run equilibrium. By contrast, dynamic CGE models explicitly trace each variable through time often at annual intervals. These models are more realistic, but more challenging to construct and solve it require for instance that future changes are predicted for all exogenous variables, not just those affected by a possible policy change. To explicitly trace each variable through time and account the second round effects, in this model we have also outlined a dynamic CGE model.

Hereafter, literatures in general equilibrium theory also classify dynamic CGE models in to two: truly dynamic (inter-temporal) and sequential dynamic (recursive) models (Cockburn, and Decaluwe, 2006). The basic difference between the two is the assumption what we have made on economic agents: truly dynamic models are those models which assume that economic agents have perfect foresight about the future, while recursive dynamic CGE model are those models which assumes adaptive expectations. Consequently, in this study we have outlined a recursive dynamic CGE model as agents are assumed to be myopic and to base their decisions on static expectations about prices and quantities.

Technically, with in this circumstance a recursive dynamic CGE model is a series of static CGE models which are linked between periods by an exogenous and endogenous variable in updating procedure. For instance, while population growth and technological changes are updated exogenously, capital stock is updated endogenously with the refection that its current level depends on its previous outcomes. Thus, according to Thurlow (2008) in a recursive dynamic CGE model, we can have both the within period (static) component, and the between periods (dynamic) component.

3.4.1. Description of static modules

In this part of the paper we try to provide the silent features of a static computable general equilibrium model for our study. Obviously, the within-period/static module of the model describes onetime effect of policy changes. Hence, the following description of the static part of model is alienated by the description of production block, trade block, the generation of institutional incomes and demand block and equilibrium block. Hereafter, the model equilibrium in static module is maintained through a series of system constraints. Although a detailed mathematical description can be found in Appendix and in Lofgren *et al.* (2002), this section presents a more discursive overview of the model's structure.

In this paper we use the standard IFPRI CGE Model (Lofgren et al., 2002).[2] In our model all markets are assumed to be competitive and hence all agents are price takers. Only endogenous prices clear factor and commodity markets in the model. A producer is engaged with an economic activity which produces one or more commodities. The aggregate final demand for commodities comes from households, activities (for intermediate inputs), government, investment, and rest of the world (RoW). The model is clutch small country assumption with no influence on the world price of its imports and exports. Imports are imperfect substitutes to domestic varieties. Likewise, there exists imperfect transformation between exports and domestic sales.

More specifically, in our model the decision of a producer at every step is dictated by profit maximization goal given the production technology and market prices for outputs, factors, and intermediate inputs. In the study profit-maximization implies that the factors receive income where marginal revenue equals marginal cost based on endogenous relative prices. Every

[2] The standard IFPRI CGE model is primarily meant for developing economies. The model is also consistent with the SAM compared to alternative models. The full list of equations is presented in Appendix A.

producer faces nested production technology.[3] At the top-level in a nested production function the producers have chooses a mix of a value added aggregate and an intermediate demand. The main premises here is that, by choosing a mix of intermediate and value added inputs the producer can maximize the profit subject to the costs of production. To determine the mix, these factors are combined with fixed-share using a Leontief specification. The use of fixed-shares reflects the belief that the required combination of intermediates and value-added per unit of output, is determined by technology rather than by the decision- making of producers. In the second level of the nesting the value added is a CES function of primary factors whereas the aggregate intermediate input is a Leontief function of disaggregated intermediate inputs. This CES specification of value added 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. The final price of an activity's output in the model is derived from the price of value-added and intermediates, coupled with taxes and subsidies that may be imposed by the government on producers per unit of output.

Household demand is represented by a linear expenditure system (LES) derived from the maximization of a Stone–Geary utility function. We have also assumed that all income generated by economic activity is distributed to consumers. Consequently, each representative consumer allocates optimally his/her disposable income among the different commodities and saving. This model includes four household categories: rural poor, urban poor, rural rich and urban rich. Households consumption include home commodities (valued at producer price), and market commodities (valued at demand prices). Households' consumption comprises domestic and imported goods. How much to consume of domestic and imported variety is dictated by a CES function as in the Armington tradition. Consequently, households maximize the Stone-Geary utility subject to their budget constraint resulting in a Linear Expenditure System (LES) demand system.

In this model we have also assumed that goods are differentiated by region of origin, including goods from abroad. In other saying, goods classified in the same sector are different according to whether they are produced domestically or imported. This assumption is frequently known as the Armington assumption. The degrees of substitutability, as well as the import penetration shares are allowed to vary across commodities and across agents. The model also assumes a single

[3] see Appendix C for the production technology figure

Armington agent. Symmetrically, on the supply side, producers make an optimal distribution of their production between exports and domestic sales according to a constant elasticity of transformation (CET) production possibility frontier. Hereafter each agent supposes to minimize the cost of obtaining in the Armington composite by choosing a best combination of imported and domestically produced goods.[4]

Households, Enterprises, Government, and RoW are the four institutions of the model. Households receive income from factors, and transfers from other institutions. Households make payments: direct taxes, transfer to rest of the world, and save. The leftover income is spent on consumption. The transaction pattern of enterprises is very similar to that of households expect the former do not consume. Government collects direct and sales taxes, and import tariffs. It also receives income from factors owned by public enterprises. Government transfers to households and to the rest of the world. It spends on public services – public administration, education, and health services. Investment demands investment goods. Investment is financed through savings from households, enterprises, governments, and rest of the world. The rest of the world demand represents foreign demand for Ethiopian exports. In addition to payments to Ethiopian exports, RoW makes transfer to Ethiopian government and households. However, it collects debt repayments, payments for imports, and transfers made by households.[5]

Finally, whether it is for the goods and services market or the factor market, our model have verified supply and demand equilibrium positions. Specifically, in this model we have defines the following equilibrium conditions:

- The equilibrium between the supply and demand of each commodity on the domestic markets.
- The equilibrium between total demand for each factor and its available supply.
- The equilibrium between total investment expenditure and the sum of agents' savings.
- The equilibrium between supplies of every commodity by local producers and domestic demand for that commodity produced locally and,
- The equilibrium between supply to the export market of each good and its demand.

[4] See Appendix D for commodity flow figure.

[5] See Appendix B for institutional income and domestic demand flow figure.

3.4.2. Description of the Dynamic module

The prototype that we have adopted in this model is a recursive dynamic structure as agents are assumed to be myopic and to base their decisions on static expectations about prices and quantities. Although the static model described above is detailed in its representation of the economy within a particular time-period, its inability to account for second-period considerations limits its assessment of the full effect of policy and non-policy changes. Therefore, to overcome these limitations, this particular study use IFPRI model by Throw (2008), where static model is extended to a recursive dynamic model in which the selected parameters are updated based on the modeling of inter-temporal behavior and results from previous periods. In the extended dynamic CGE model, in one hand, the current economic conditions like the availability of capital, are set to be endogenous (i.e. its value depend on its past outcomes), on the other hand, some variables like population are set to exogenously update based on observed or separately calculated projected trends.

In the so-called Business-as-Usual scenario, the dynamics nature of the model is calibrated by imposing the assumption of a balanced growth path. The dynamics nature of the model has originated from the accumulation of productive capital.[6] The process of capital accumulation is modeled endogenously, for instance, in the basic capital accumulation function the current capital stock is equal to the depreciated stock inherited from the previous period plus gross investment. In every period the capital stock is updated with a capital accumulation equation. Moreover, the motion equation for the aggregate capital stock is given by the following 1-step formula:

$$K_t = (1-\sigma)\, K_{t-1} + I_{t-1}$$

$where$, K is the aggregate capital stock, σ is the annual rate of depreciation, I_{t-1} is the level of real investment in the previous period.

As well, the dynamic recursive model what we have adopted in this study has calibrated on the exogenous growth rates of population, real government consumption, current account balance, transfer spending and real wages. Population growth is exogenously imposed on the model based on separately calculated growth projections. It is assumed that a growing population generates a higher level of consumption demand and therefore raises the supernumerary income level of household consumption. There is assumed to be no change in the marginal rate of consumption

[6] A detailed mathematical description of the dynamic module can be found in Appendix and in Lofgren *et al* (2002)

for commodities, implying that new consumers have the same preferences as existing consumers. Additionally, in our model unskilled, semi-skilled and skilled labor supply within a particular time period is set to be infinitely elastic at a fixed real wage. As such it is the real wage, rather than labor supply, that adjusts between periods. Therefore, the exogenous adjustment of labor supply (QFS_f) is unnecessary since there are no constraints on factor supply. Rather, it is necessary to exogenously adjust real wages.

3.4.3. Social Welfare Module

For the sake of households' welfare calculation, in this model we have adopted Hicks Equivalent Variation. Conveniently, in this method we have calculated households' utility through the demand changes based on commodity prices that we have observed before the policy implementation using the following formula:

$$EV = E(U^2, PQ^1) - E(U^1, PQ^1) = \sum_i PQ_i{}^1 * HD_i{}^2 - \sum_i PQ_i{}^1 * HD_i{}^1$$

where, EV is the equivalent variation of households' welfare, and $E(U^2, PQ^1)$ is the utility after the policy implementation calculated by the payment function based on price before the policy implementation; $E(U^1, PQ^1)$ is the utility before the policy implementation; $PQ_i{}^1$ is the price of commodity i before the policy implementation; $HD_i{}^1$ and $HD_i{}^2$ are the households' consumption before and after the policy implementation, respectively. Therefore, EV is calculated by using the above one-step formal formula. At the end of the day, a positive EV figure that we have obtained from the formula means that there is an improvement in social welfare whereas, the negative figure implies that there is deterioration in social welfare after the implementation of the policy.

3.4.4. Model closures

In view of the fact that CGE models contain more variables than equations, therefore, it is necessary to specify and choose which of these variables will be determined endogenously within the model and which variables will be determined exogenously. Thus, the assumptions that we have concerning in the choice of these endogenous and exogenous variables are known as the model closure and should be designed in a way that reflects the desired economic environment under which the simulation is to be run (Dixon et al., 2013).

Our model is run for 16 periods. All commodity markets follow the neoclassical market-clearing system in which each market is cleared when the total endogenous demand equals the total supply through price adjustment. World import and export prices are set fixed following the small price-taking economy hypothesis. Labor is assumed to be mobile across activities; whereas land and non-agricultural capital are assumed to be activity specific implying that sector-specific wages adjust to ensure that demand for capital equals total supply. To account for the situation on the labor market in Ethiopia unemployment amongst unskilled, semi-skilled, and skilled labor is assumed to be sufficiently large such that wages are fixed in real terms and labor supply passively adjusts to match demand. This assumption is appropriate in settings where there is considerable unemployment for a given labor category. Compared with the default closure, the only change is that the economy-wide wage variable is now fixed while the supply variable is flexed. Hereafter, each activity is free to hire any desired quantity at its fixed, activity-specific wage. As well, the Consumer Price Index (CPI) is the numeraire of the model. Since the model is homogeneous of degree zero in prices, a doubling of the value of the numéraire would double all prices but leave all real quantities unchanged. Hereafter, all simulated price and income changes should be interpreted as changes vis-à-vis the numéraire price index.

Moreover, there are three macro balances: Government balance, external balance and saving-investment balance. The model macro closures combination is Johansen type. For the savings-investment account, real investment is fixed at initial level, and thus, savings will adjust to investment to keep the savings-investment (S-I) balance. On government balance, real expenditures and tax rates are set fixed and government savings (the difference between current revenues and expenditure) are flexible. Here, the budget balance adjustments are done by the government through a change in direct and indirect tax receipts. This closure is chosen since it is assumed that changes in direct and indirect tax rates are politically motivated and thus are adopted in isolation of changes in other policies or the economic environment. For external balance the level of foreign savings is fixed in foreign currency terms. In this context, any widening of the trade deficit due to growth in imports exceeding growth in exports must therefore be offset through an overall reduction of spending on imports from all sources together with an overall increase in export earnings. This response is implicitly affected through a real exchange rate adjustment (current times Ethiopia use devaluation policy). Therefore, the study use flexible exchange rate and fixed foreign saving.

3.4.5. Simulation designs

Assessing the economic wide effect of Ethiopian renaissance dam to Ethiopian economy requires economic scenarios that can be simulated with the dynamic CGE model for Ethiopia economy to be defined. Unfortunately, the macro closure of the model imposes restrictions on the type of scenarios that will simulate. Additionally, the simulation exercise by itself requires the definition of a baseline scenario that can be used as a benchmark to measure the impact of a given policy scenario's. Hence, this scenario is run and provides "what if" or counterfactual projections, rather than a forecast.

In a consequence, since the main objective of this paper is to assess the potential economic impacts of Ethiopian renaissance dam to Ethiopian economy and currently she has announced a national energy policy, it makes sense to assess the impact of policy prescriptions on Ethiopian's economy. For this sake, we have considered the economic scenario that will be compared with the result of the baseline run. Given the additional electricity generation capacity of Ethiopia, we run a policy simulation in which the additional 6000MW that scheduled to come online near the future form renaissance dam. Specifically, given that there is no additional power generation capacity expected from Ethiopian renaissance dam between the years 2010 to 2017, the electricity supply growth is set to be zero. However, in 2018 there is additional power generation capacities which expected to come online from Ethiopian renaissance dam. Hence, in this year electricity supply growth is set to 17.5 percent.[7] This simulates the new generating capacity of GERD which come online over this period (i.e. two turbines of GERD each with capacity 375 MW have already been installed and are waiting test electricity generation). From 2019 onward, electricity supply growth rate is set to 94.4 percent in our policy run.

[7] This growth rate electricity supply is computed by the following formula which interpreted as the smoothed annualized growth rate achieved during the considered time horizon where *n = number of periods*

$$\sqrt[n]{\frac{\text{ending value}}{\text{beginning value}}} - 1$$

Chapter four

4. Discussion and analysis

4.1. Overview of the Ethiopian Economy – A Social Accounting Approach

This sub-section discusses some of the structural characteristics of the Ethiopian economy based on 2009/10 SAM which we have depicted in table 4.1 below at aggregated level.

4.1.1. The Ethiopian Economy

The gross domestic product[8] (GDP) at market price is approximately 355 Billion birr; this comes from all activities within the economy. The service sector is the largest contributor to GDP (around 45.07 percent). The services sector is the most important in terms of share in GDP, share of total output and share of exports. Its share in total household consumption is relatively low amounting 22.2 percent. Agriculture produced 32.3 percent of total output. Its share in GDP is 44.74 percent. It represents 39.4 percent of exports and 41.7 percent of household consumption. The manufacturing sector is highly dependent on imports as 56 percent of total domestic supply is imported (manufacturing products represent 69.4 percent of imports) while only representing 10.19 percent of GDP and 14.4 percent of output.

4.1.2. Total Value Added

Total value added, i.e. earnings received from the factors of production (capital in the form of profits paid to capital and labor in the form wages) is also known as GDP at factor cost. Value added is labor-intensive in agricultural sectors (75.2 percent) while manufacturing and services sectors are intensive in capital (61.9 percent and 77.8 percent). Agricultural labor and land are only employed in agricultural production. Non agricultural capital is employed by manufacturing and services sectors and livestock capital is only utilized in agricultural production. Overall value added is intensive in labor (48.5 percent) followed by capital (44.9 percent). Disaggregated to skilled, unskilled and semi-skilled labor, more skilled labor is found in the social sectors of education and health. The agriculture sector has unskilled and semi-skilled labor.

4.1.3. Intermediate Demand

Intermediate demand shows the demand for commodities and services used in the production process. Hence, Value added is combined with intermediate consumption of goods and services to produce sector output.

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[8] This is given by the identity GDP= C+G+I+X-M i.e. GDP= private consumption +government consumption + investment + exports - imports.

	Agr	Ind	Serv	CAg	CInd	CServ	trc	flab-sk	flab-ss	flab-un	flab-ag	fcap	flnd	fliv	gov	hh-rur-pr	hh-rur-npr	hh-u-pr	hh-u-npr	dtax	mtax	stax	dstk	s-i	row	total
Agr				**189.8**																						**189.8**
Ind					**158.2**																					**158.2**
Serv						**250.3**																				**250.3**
CAg	**8.31**	**24.5**	**12.1**													**40.20**	**105.08**	**1.5**	**6.34**				**1.82**	**0.3**	**13.9**	**213.9**
CInd	**5.75**	**86.7**	**51.8**													**16.17**	**67.33**	**1.2**	**12.69**					**85.2**	**12.2**	**338.9**
CServ	**1.51**	**10.9**	**42**				**83.8**								**31.82**	**13.81**	**65.56**	**0.7**	**8.01**						**26.1**	**284.2**
trc				**14.9**	**68.9**																					**83.8**
flab-sk		**1.8**	**18.6**																							**20.47**
flab-ss	**3.36**	**12.9**	**40.8**																							**57.04**
flab-un	**30.8**	**2.8**	**5.8**																							**39.39**
flab-ag	**57.1**																									**57.08**
fcap	**12.3**	**18.7**	**79.3**																							**110.32**
flnd	**39.8**																									**39.76**
fliv	**30.9**																									**30.86**
gov																				**5.6**	**9.59**	**18.8**			**33.8**	**67.78**
hh-rur-pr								**0.36**	**9.06**	**8.46**	**20.27**	**6.29**	**14.09**	**10.96**	**0.46**										**3.9**	**73.93**
hh-rur-npr								**10.7**	**43.75**	**26.64**	**36.81**	**87.65**	**25.67**	**19.89**											**9.9**	**261.1**
hh-u-pr								**0.33**	**0.72**	**0.88**		**1.55**			**0.009**										**0.3**	**3.8**
hh-u-npr								**9.07**	**3.5**	**3.42**		**14.92**													**4.6**	**35.54**
dtax																	**3.12**		**2.48**							**5.6**
mtax				**0.001**	**9.6**																					**9.59**
stax				**0.38**	**15.6**	**2.8**																				**18.8**
dstk																								**1.82**		**1.82**
s-i															**35.49**	**3.75**	**19.98**	**0.4**	**6.02**						**21.7**	**87.31**
row				**8.8**	**86.5**	**31.2**																				**126**
total	**189.8**	**158.2**	**250.3**	**213.9**	**338.9**	**284.2**	**83.8**	**20.47**	**57.04**	**39.39**	**57.08**	**110.32**	**39.76**	**30.86**	**67.78**	**73.93**	**261.1**	**3.8**	**35.54**	**5.6**	**9.59**	**18.8**	**1.82**	**87.31**	**126**	

Table4.1: Ethiopian Macro SAM in billion birr

Agriculture is intensive in value added and uses little intermediate consumption. The manufacturing sector is relatively more intensive in semi finished and finished goods and services as intermediate inputs. In contrast, the services sector is intensive in intermediate inputs. Intermediate consumption constitutes 39 percent of the total demand. The disaggregated SAM provides information on production technologies, i.e. how much input is used per unit of output. Regarding the nature of these intermediate inputs, agriculture uses 47 percent of agricultural products, 37 percent come from manufacturing essentially composed of fertilizers and chemicals. It also uses services mainly financial services. The manufacturing sector uses 62 percent of manufacture products, 23 percent of agriculture products and 15 percent of services. 70 percent of agricultural inputs are demanded by agro processing industries. The services sector uses 50 percent of its intermediate inputs from the manufacturing sector and 44percent from the services sector.

4.1.4. Factor Income Distribution

Households receive their incomes from labor and transfers from government, enterprises, and ROW. Income from labor forms the highest proportion of household income source (41 percent), followed by transfers from government (30 percent), and remittances from abroad (28 percent). With the disaggregated SAM, one can establish the sectors from which poor households obtain most of their income, with rural households obtaining most of their incomes from the agricultural sector while the rich urban households derive their incomes from manufacturing and services. 63.4 percent of income from skilled agricultural labor is distributed to non poor rural households and the remaining to poor rural households. The share of the two households is similar regarding unskilled agricultural labor. Non agricultural labor is distributed among urban households. 15.7 percent of irrigated land and 10 percent of non-irrigated land income is distributed to poor rural households. The remaining goes to non-poor rural households. Livestock income is distributed to the two rural households (respectively 32.6 percent and 67.4 percent). Non-poor rural households receive 60percent of non-agricultural capital. The remaining is mainly distributed between public firms (10.8 percent), non-poor households in small urban settlements (13 percent) and poor rural households (7.3 percent). Land income is low representing 3.7 percent for poor rural households and 10.6 percent for the non-poor rural. Its share is much less than livestock income (7.6 percent and 5.2 percent). Non-agricultural capital represents 16.2 percent and 41.1 percent of poor and non-poor rural households. Public firms earn almost all their income from non-agricultural capital. 80.9 percent of government income comes from taxes while the remaining is from transfers. The rest of the world income is composed of return to capital (4.4 percent), transfers (22.6 percent) and exports (73 percent).

4.1.5. Foreign Trade

Exports constitute almost 10 percent of domestic production. Export intensity is low averaging 9.1 percent. 11.1 agricultural products are exported although they represent nearly 40 percent of total exports. Services are exported to 6.7 percent representing 39 percent of total exports and manufactured products to 13.7 percent. Import penetration amounts nearly 20 percent of total domestic supply with manufacturing products reaching 56 percent while agricultural products are mainly locally supplied with only 4 percent of imports. The top two import non-food manufactured products for Ethiopia are petroleum products and transport equipment. Total imports almost double exports, implying a huge negative trade balance.

4.2. Policy Simulation Results

The main rationale of this paper is to provide an economy-wide examination of the contribution that additional power generation from Ethiopian renaissance dam will make to Ethiopian economy over the coming years. In this circumstance, to conduct our analysis we use a recursive dynamic computable general equilibrium (CGE) model for Ethiopian economy. We use changes in real GDP, sectoral productions, employment, external sector, prices, household income, household consumption expenditures and welfare effects relative to the baseline as indicators of the economic wide effects of the dam. We are then able to interpret the contribution of Ethiopian renaissance dam as the deviations in the absolute values of the economic outcomes between the baseline and policy simulations.

All at all in this section we focuses on unfolding our experimental simulation and the modeling approach which have been conducted to examine the economy-wide effect of Ethiopian renaissance dam to Ethiopian economy. Intentionally in this section the policy simulation results are expressed as percentage deviations relative to the baseline, unless otherwise we stated. In this part, although we present results for all years of simulation, we pay particular attention to analyzing results for the years 2018 and 2025, which respectively corresponds to the implementation period of Ethiopian renaissance dam and end of the simulation period. Now let us scrutinize our simulation results more plainly.

4.2.1. Macroeconomic effects

As a basic industry of the national economy, the electricity industry plays an irreplaceable role to support economic development. Thus, the impacts of Ethiopian renaissance dam on GDP should be put in the first place in order to know the power effect better. To do so, the simulation results in this study are presented in a series of real GDP growth, consumption, real investment, export and import deviation from baseline scenarios.

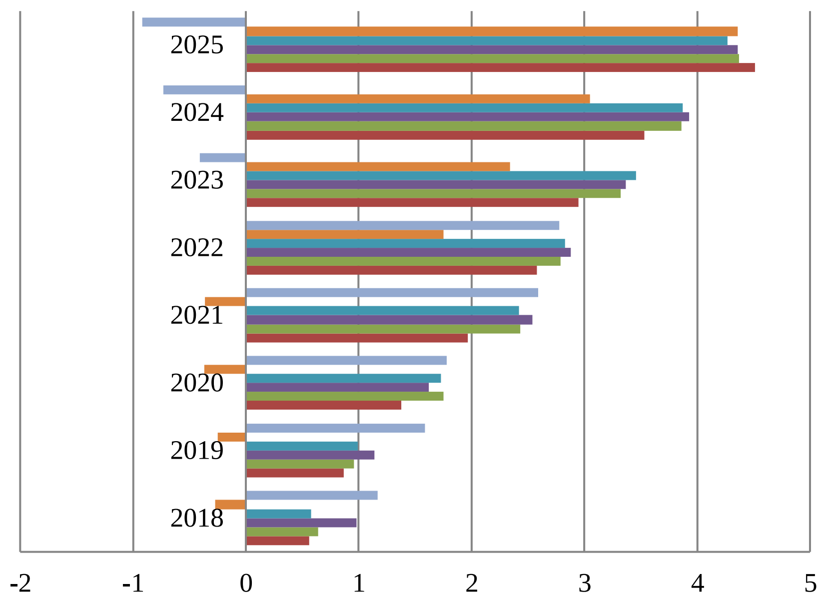
As shown in Figure 4.1 below, the positive impacts of Ethiopian renaissance dam on GDP are very significant. This change in the GDP is attributed to the change in the GDP distribution due to the reallocation of the factors of production, intermediate inputs among all domestic production sectors, change in the level of consumption and net trade. In opting of our policy shock, GDP gain accelerates with an additional power supplies resulted from Ethiopian renaissance dam, i.e. on average Ethiopian GDP grows by 2.29 from the year 2018 to 2025 compared to the baseline scenario. The findings obtained in this study are similar to the findings of (Bohlmann, et al., 2015; Levent, 2010; Robinson & Gueneau, 2014; Kenneth et al., 2007; and Tewodros et al., 2015) who document a definite positive relationship between hydroelectricity consumption and GDP growth rate.

The effects of Ethiopian renaissance dam on GDP are also presented as the result of the output increment in the electricity sector itself (i.e. the direct effect) and the increment in the output of other sectors resulted from additional electricity supply. Lin and Liu (2016) point out that, in the stage of the industrialization and urbanization process, there is a relatively stable 1:1 relationship between the growth rates of GDP and electricity consumption in the long term. Sensationally, our result is also consistent with this finding. This is because CGE model offers equilibrium results, where industries would move from low power-consuming sectors to high power-consuming ones in the case of a power supply increment.

More pronouncedly, Figure 4.1 shows that in our experimental scenario with the additional power supply via the construction of Ethiopian renaissance dam, Ethiopian economy shows a good growth trend. GDP grows regularly. It is increased by 0.56 percent in 2018, by 1.97 percent in 2021 and by 4.51 percent in 2025 relative to the baseline scenario. Consequently, in opting for a policy targeting of an increment in electricity supply via the construction of Ethiopian renaissance dam, the country can optimize the beneficial impacts on its economy. And so, over the simulation periods the best returns are from the construction of Ethiopian renaissance dam.

This can explained through productivity gains induced in the industrial and manufacturing sectors that have larger spillover effects with additional power supplies.

Figure4.1: The effect of GERD on macroeconomic variables (year on year deviation from its baseline scenario)



	2018	2019	2020	2021	2022	2023	2024	2025
Import	1.17	1.59	1.78	2.59	2.78	-0.41	-0.73	-0.92
Export	-0.27	-0.25	-0.37	-0.36	1.75	2.34	3.05	4.36
Government consumption	0.58	0.99	1.73	2.42	2.83	3.46	3.87	4.27
Investment	0.98	1.14	1.62	2.54	2.88	3.37	3.93	4.36
Household consumption	0.64	0.96	1.75	2.43	2.79	3.32	3.86	4.37
Real GDP	0.56	0.87	1.38	1.97	2.58	2.95	3.53	4.51

Source: GMAS result and authors' own calculation

On the external sector, in opting of our policy shock, the result of the exercise showed that real export of the country has reduce in the first four simulation periods (i.e. reduced by 0.27 percent in 2018, by 0.25 percent in 2019, by 0.37 percent in 2020 and by 0.36 percent in 2021). This finding is in line with the finding of Bohlmann et al. (2015), but contrary with the result by Levent (2010). This result is explained by the appreciation of real exchange rate (i.e. on average by 0.75 percent) which resulted from the increment in electricity export to neighboring countries. In the viewpoint of domestic producers, appreciation of real exchange rate per se reduces in tendency of the price of exports relative to the price in the domestic market, and thus producers shift their optimal profit-maximizing output mix between export and home market production in favor of the latter. As well, an appreciation of real exchange rate makes import cheaper and export expensive in world market this induce firms to import more and export less; and hence, reduce the competitiveness of trade sectors. Therefore; in opting of our policy shock, an appreciation or overvaluation of real exchange rate become inimical to export performance. However; in the last four simulation periods the real export grew at a positive rate even if the real exchange rate is continued to appreciate until 2023. This part of the result is in line with the finding by Levent (2010), where doubling of electricity increases export on average by 0.31 percent in turkey. This might be presented as the total factor productivity effect of GERD on sectors which have highly linked with electricity (i.e. industry and manufacturing sectors) coupled with the reduction in production costs exists with the additional power supply from renaissance dam. Moreover; the possible combined effect of increase in total factor productivity and lower appreciation of the real exchange rate in later simulation periods result in a positive growth of real export. Therefore; on balance these cheerful supply side effects of additional power supplies via construction of renaissance dam on the productivity of different sectors surmount the possible negative effects of the appreciation of the real exchange rate.

Conversely to export, in our policy experiment import volumes rise in line with an increment in factor income and consumption in the first five shock periods. Imports rise by 1.17 percent in 2018, by 1.59 percent in 2019, by 1.78 percent in 2020, by 2.59 percent in 2021 and by 2.78 in 2022 relative to the baseline scenario. These estimates confirm most of the empirical results found in the literature which examine the economic-wide effect of electric power generation plants (For instance; Bohlmann, et al., 2015; Levent, 2010; Robinson & Gueneau, 2014; and Kenneth et al., 2007). This result is explained by the increment in factor income and the appreciation of real exchange rate resulted from the construction of renaissance dam via supplying additional power to the economy. The intuition is that, for instance; in the perspective of domestic residents, an appreciation of real exchange rate reduces the price of imported product relative to domestically produced goods. This induces a substitution effect towards imports for commodities in cases where the exchange rate effect dominates the simultaneous drop in the prices of domestic output due to the electricity price reduction in the new equilibrium. This substitution effect affects both imports of final goods and intermediate inputs. Factor income distribution as well shapes the import demand patterns in important ways and implies the orthodox conclusion that – *ceteris paribus* – the rise in factor income increases the volume of domestic imports. Consequently, consuming a narrow range of imported product may simply reflect a narrow range of factor income, with no particular welfare loss. However; in the last three post-shock periods, real imports volume do decline (i.e. reduced by 0.41 percent in 2023, by 0.73 percent in 2024 and by 0.92 percent in 2025). This result highlighted a significant shift in the consumption pattern of domestic consumers from the imported to domestic products, and the increment in the competitiveness of domestic production capabilities to match its counterparts due to the improvement in the ease of doing business with additional power supply from renaissance dam.

On investment level, as it is part GDP components, the construction of Ethiopian renaissance dam induce the capital stocks to rise over the medium and long term in line with the rise in factor returns. This result is in line with the finding by Levent (2010), Bohlmann et al. (2015) and Guntilake H. and Roland-Holst D. (2013) who documents a positive effect of additional power supply and real investment. This could be illuminated with the fact that, as the accelerator theory states, when businesses see an improvement in factor income and economic forecasts, they will increase their investment to meet future increment in demand. In other saying, if factor income increases via the construction of Ethiopian renaissance dam, as the economy is on an up-turn, this induces investment spending in the economy to rise. Our results also confirm this and show that investment expenditure will rise by 0.98 percent in 2018, by 2.54 percent in 2021 and 4.36 percent in 2025, compared with the baseline scenario.

In sequence of events, we have also scrutinizing the question how does the construction of Ethiopian renaissance dam affect consumption pattern? This question is crucial for understanding consumers’ behaviour and to evaluate our policy changes impacts on households’ resources. Indeed, in virtually consumption represents more than two thirds of GDP, thus knowledge of how consumers respond to income change with additional power supply from Ethiopian renaissance dam is also crucial for evaluating the macroeconomic impact thoroughly. Consequently, in opting of our policy simulation, it is obvious that the construction of Ethiopian renaissance dam increases factor income through backward and forward linkages (we will discuss this situations in the later sub-section) and hence, consumption. Symmetrically, the result of the exercise showed that an additional power supply from Ethiopian renaissance dam increases household’s consumption in line with increased factor income, but the short-term increases in income affect consumption less than long-term increases. Household’s consumption rise by 0.64 percent in 2018, by 2.43 percent in 2021 and by 4.37 percent in 2025 relative to the baseline scenario. The empirical results obtained in this study are consistent with the finding by Levent (2010) and Bohlmann et al. (2015) who find a positive relationship between expansions of power plants and household's consumption. In the same fashion, through power exports Ethiopian renaissance dam have also contributed significantly to a rise in government revenues via increases in the corporate tax revenue and surplus transfers. Accordingly, the government expenditure rise in line with increases in government revenue. Our result also confirms this generalization (i.e. government spending increase by 0.58 percent in 2018, by 2.42 percent in 2021 and by 4.27 percent in 2025). This finding could also be presented as a result of rising in tax revenues in line with increase in economic activity from additional power supplies. In a consequence, the budget deficit slightly becomes narrow and narrow in the long term relative to the baseline scenario.

Therefore; from this evaluation we can confidently conclude that Ethiopian renaissance dam should be brought online as expected in the simulation design, since its contribution on GDP components has shown as being unambiguously good for the economy.

4.2.2. Impact on real output by sector

Macroeconomic effects that we have seen before, however; represent aggregate impacts. We further need to investigate these effects on different activities of the economy. The impacts of Ethiopian renaissance dam on the output of various sectors have shown in figure 4.2 below. As can be seen, the impacts of additional power supply from renaissance dam on various sectors are different. The impacts of Ethiopian renaissance dam on real output are fairly positive for almost all the sectors because the construction of Ethiopian renaissance dam benefits all sectors through a reduction in margin costs.

The immediate impact of the construction of Ethiopian renaissance dam is therefore; a significant expansion in output of electricity sector itself. This output expansion in electricity therefore; results in a higher demand for intermediate inputs thereby creating a spillover effect to the rest of the economy (i.e. as other sectors also increase their production to meet higher demand of their products). As a result, employment and returns to factors of production increases as well. Consequently, this higher in return to factors creates a snowball effect, as greater profitability in the electric sectors attract further investments. This is true especially for the sectors which have the strongest forward linkages with electricity. Thus, from our exercise one can ardently conclude that almost all sectors increase production relative to the baseline scenario due to the fact that the reduction in margin costs contributes to the reduction in the cost of production in post shock periods. For instance, the heavy industry and the light industry are the most susceptible industries, whose output increases as power supply increases. As well, construction and the service industries are also heavily correlated with the supply electricity from renaissance dam. Their production levels are affected positively as well. In contrast to other sectors the output of the oil was showing reduction (we will explain this later).

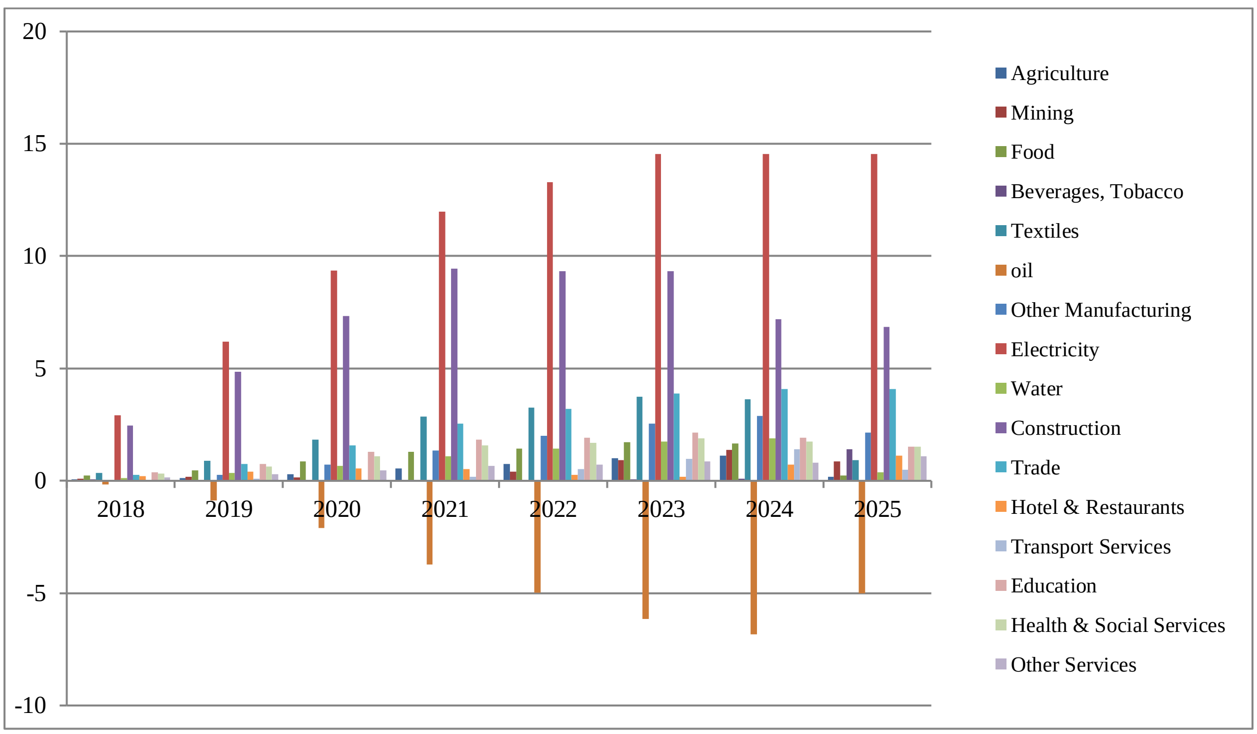
To look at the effect more amassed; the output of all activities in the agricultural, industrial and service sectors are aggregated for the entire periods. Then average percentage change in output for each sector is calculated from aggregate output growth. On an industry level, the electricity and construction industries are the biggest contributors to the positive changes in overall industry output. This is expected, given that these are the two industries most directly affected by the shock imposed in our policy simulation. This can also be associated with the adjustment of the economy to a higher capital stock, which consequently causes a positive deviation in the ratio of investment relative to GDP. Accordingly, among the sectors, the largest expansion is shown by the industrial and manufacturing sector, it has increased on average by 4.5 percent followed by service sector (i.e. 2.8 percent) compared with the baseline scenario from 2018 to 2025. This is because on the production process industrial sector is one of the major users of electricity as an intermediate input. Therefore, total factor productivity of industrial sector improves more following additional power supply from Ethiopian renaissance dam shock and it explains the expansion of the output in the sector. The same is true for service sector.

The construction of Ethiopian renaissance dam, on the other hand, has the least effect on agricultural sector because agricultural sector has limitedly use electricity as an intermediate input in its production processes in most part of country. In the economy, human effort contributes above 75 percent of the power required for land preparation and subsequent weeding, the principal demand peaks in the farming cycle. Hence, it is not surprising that agriculture is the least favored sector with additional power supply from Ethiopian renaissance dam. Consequently, in opting of our policy scenario, agriculture sector has recorded least growth rate its output raises by 0.28 percent compared with the reference scenario.

All at all, from the above results we can scrutinize the following three sweeping statements:

- ✓ First; as a basic input for the national economy, additional power supply from Ethiopian renaissance dam makes the output of almost every sector increases.
- ✓ Second; the increments in the production of sectors indicating that under the background of a long-term power supply from the renaissance dam, industries transfer to high power-consuming sectors from low power consuming one.
- ✓ Lastly; as an energy inputs, a contrary trend is observed for oil output. This is due to the facts that as a power supply sources, the oil department of electricity and its counterpart's hydropower mostly reflects a substitution effect. So, the increment in electricity supply form renaissance dam leads to an increment in rigidly in oil output. In other saying, for the power supply increment in Ethiopia over the coming years, many small and medium-sized enterprises used electricity for power generation; thus the oil output did not rise, but falls.

Figure4. 2: The effect of GERD on real output by sector (Cumulative Percentage Difference Relative to Baseline).



Source: GAMS result and Author's Own Calculations

4.2.3. Effects on employment

Recent experience has shown that it is not only economic growth, but also the pattern of growth which matters for sustainable and inclusive development. Explicitly speaking, even if employment generation is a key element for an inclusive and job rich growth strategy, now a day there is a world-wide phenomenon of job-less growth. In this milieu, the construction of Ethiopian renaissance dam is not just about growth. It can indeed be about jobs as well. Consequently, we have to scrutinizing the question how does the construction of Ethiopian renaissance dam alter the employment patterns in the economy? This question is crucial for understanding how employment will reacts to the construction of Ethiopian renaissance dam and to evaluate our policy change impacts on growth through employment opportunities.

Regarding to employment, the construction of Ethiopian renaissance dam has a positive impact almost in all sectors. More specifically, in opting of our policy shock (the increment in power supply from Ethiopian renaissance dam) skilled workers employment grows most in the manufacturing and industry sectors (see figure 4.3 below), semi skilled workers employment grows most in services sectors, and unskilled workers employment grows most in agriculture sector in all our simulation periods (see figure 4.4 and 4.5 below). As well, in setting a policy scenario of power increment, the rate of growth of demand for skilled labors compared to the reference scenario is stronger in the industry and manufacturing sectors, followed by service and electricity sectors but it declines in the agriculture sector. It happens as though there is a reallocation of workers. This is all the more relevant because improving factor productivity and reducing electricity blackouts through increasing electricity infrastructure makes it possible to increase demand for labor in sectors which use the electricity most intensively. Hence; skilled workers in the manufacturing and industry sectors benefits more than average from the construction of Ethiopian renaissance dam.

In terms of unskilled labors, the policy measure has effect of increasing labor demand by more than the reference scenario in the agriculture sector. However, its expansion in the manufacturing, electricity and service sectors are comparatively limited. This is due to the fact that with additional power supply from renaissance dam jobs that require unskilled labor are continually shrinking due to technological and societal advancements. With raise in production and productivity via additional power supply, jobs that previously required little or no training now require training. In a consequence, semi-skill labor addresses the increment in the demand for skills in the economy, even for less complex jobs. At a meantime jobs become more complex than those that can be performed by a non-skilled laborer even in agriculture sector. However, they do not require highly specialized skills. Consequently, our results also confirm this and show that the employments of semi-skilled labors are rise almost in all sectors relative to the baseline scenario in all simulation periods.

Figure4.3*: Impact of Ethiopian renaissance dam on demand for skilled labour (percent change with respect to reference scenario)*

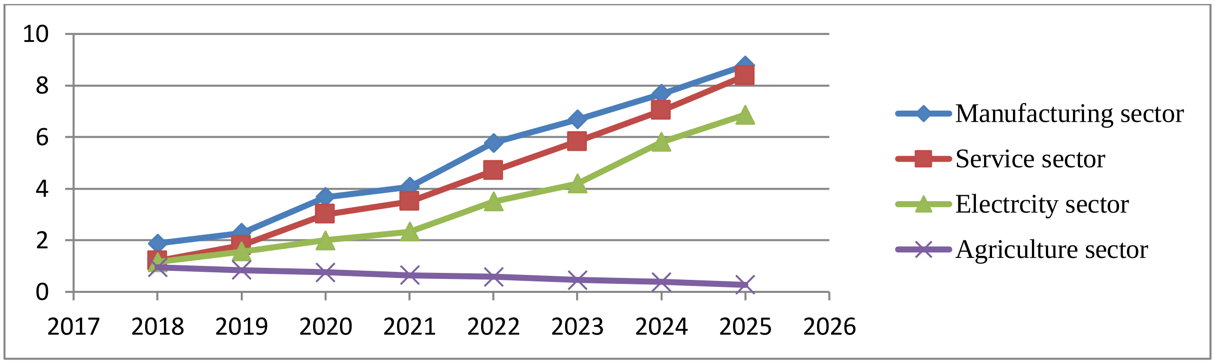


Figure4.4*: Impact of Ethiopian renaissance dam on demand for semi- skilled labour (percent change with respect to reference scenario)*

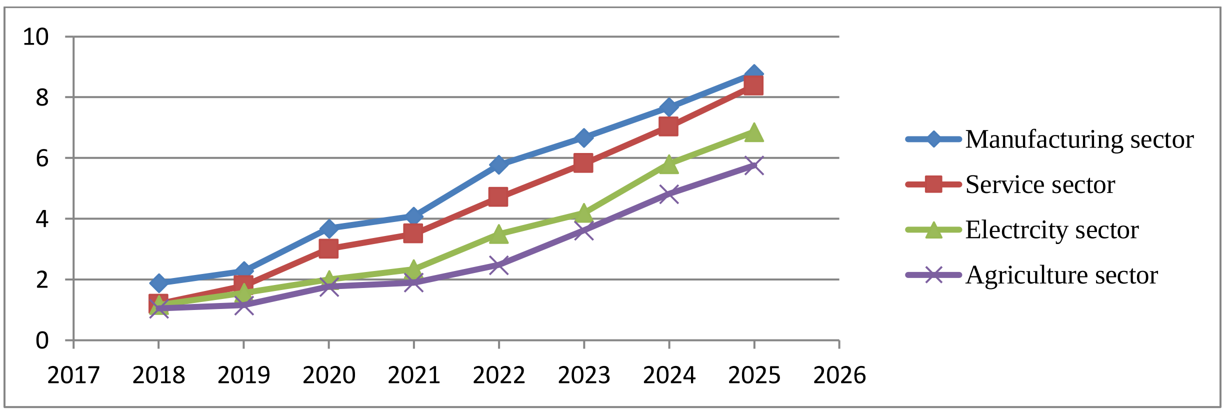
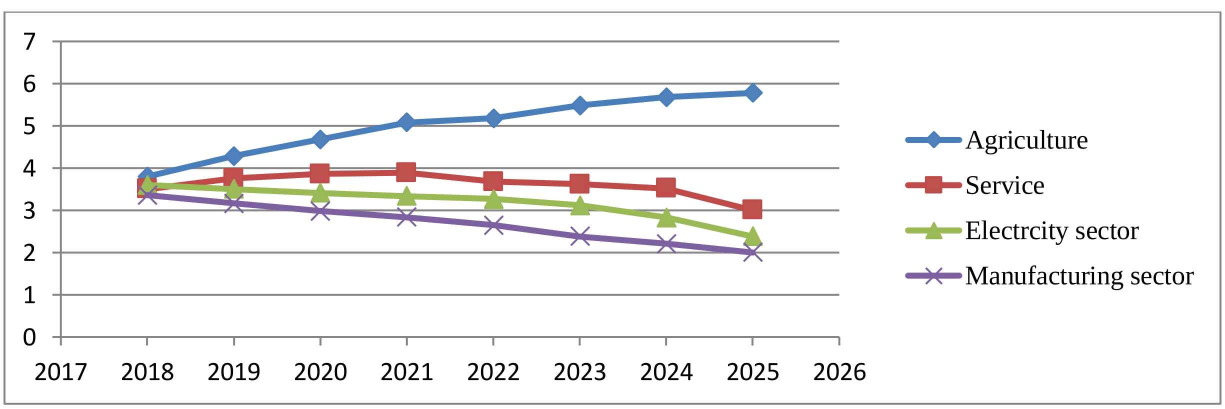


Figure4.5 *: Impact of Ethiopian renaissance dam on demand for unskilled labour (percent change with respect to reference scenario)*



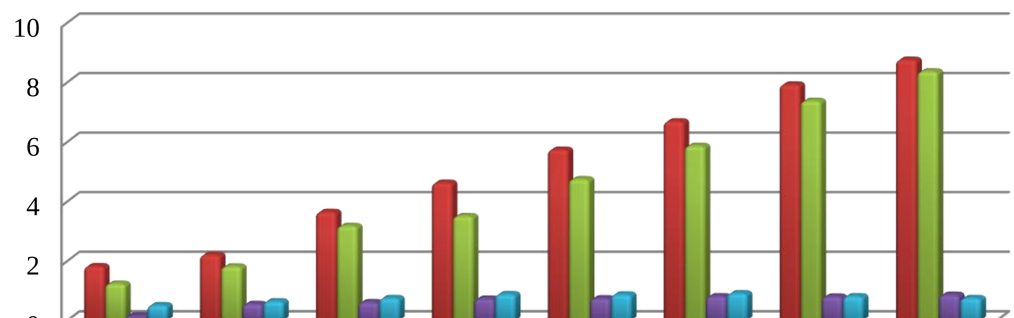
Source: GMAS result and authors' own calculation

In a nutshell, the biggest impact of Ethiopian renaissance dam on the labor market in the short and long run is observed due to the increment in the levels of productivity, stemming from the excess of electricity generation capacity and the rise in investment expenditures.

4.2.4. Impacts on factor income

Regarding to the effects of GERD on the functional income distribution – that is the distribution of primary income by type of factors – Figure 4.6 displays the impacts on real factor returns relative to the baseline scenario in the corresponding years. Turning to returns of factors of production, the simulation result of the exercise found that aggregate income of factors of production in all simulation periods are slightly higher than the baseline. On balance, in our simulation periods we have observed that higher-growing sectors are relatively skill- and capital-intensive and thus their additional factor input demand drives up capital returns and skilled wages more than unskilled wages. Consequently, among the factors of production in our model, the return of capital grows at the fastest rate. It grew by 1.83 percent in 2018, by 4.63 percent in 2021 and by 8.76 percent in 2025 compared to the baseline scenario.

Figure4.6: The effect of GERD on factor income (percentage change from the reference scenario)



	2018	2019	2020	2021	2022	2023	2024	2025
Capital	1.83	2.21	3.65	4.63	5.74	6.69	7.93	8.76
Labor	1.24	1.82	3.18	3.51	4.75	5.87	7.38	8.37
Land	0.16	0.56	0.62	0.74	0.75	0.82	0.81	0.87
Livestock	0.52	0.65	0.76	0.89	0.88	0.92	0.82	0.76

Source: GAMS result and Author's Own Calculations

The intuition is that an additional power supplies from Ethiopian renaissance dam affects the returns of capital by affecting the productivity in industrial and service sectors, which are relatively more capital intensive compared to agricultural sector. Subsequently, capital owners will unswervingly benefit from the additional power generated from Ethiopian renaissance dam.

Therefore, from this exercise one can conclude that the fast growth rate what we have observed in these sectors can result with an improvements in returns of capital.

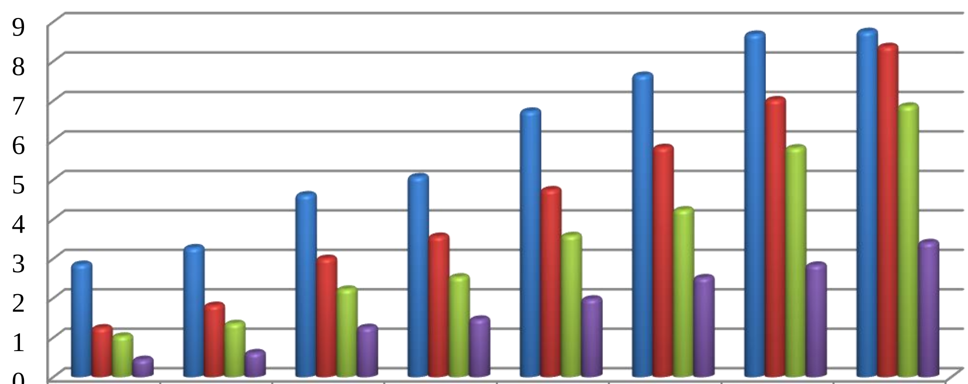
As it can be seen from figure 4.6 above, in opting of our policy shock the aggregate income of labor has recorded positive growth compared with the baseline scenario. It has increased by 1.24 percent in 2018, by 3.51 percent in 2021 and by 8.37 percent in 2025 compared to base line simulation. The reason is emanates from fact that the higher-growing sectors what we have observed in our simulation are relatively skill and capital intensive and thus their additional factor input demand drives up skilled and semi-skilled returns more than the reference scenario. Consequently, the increment in returns of semi skilled and skilled labor offsets the reduction in returns of unskilled labor. Pronouncedly, the increment in income of skilled and semi-skilled labor is may be due to expansion in the output of tradable sector in our simulation. On the contrary, almost in all simulation periods the result of our exercise showed that in opting of our policy shock the returns of land and livestock are slightly rises but at a lower rates. The reason for the reversal of the effect on agricultural land rents and livestock is related to the fact that electricity use in agriculture sector is very low. Thus, in our policy shock agriculture benefits very little from additional electricity supply via the construction of Ethiopian renaissance dam and electricity price reductions.

4.2.5. The effect of GERD on Household's Income

The income effect of the construction of Ethiopian renaissance dam via supplying additional power supply on household is captured through its impact on factor income and income from transfers. This is due to the fact that the primary sources of income for households are emanates from factor payments and transfers from other institutions. In our policy shock, with the rise in the production and productivity of almost in all sectors through additional power supplies, workers will see their nominal returns to rise (see figure 4.6 below). In consequence the nominal income of both poor and non poor households in both urban and rural areas has improved. However, since the urban and rural high-income groups have higher shares of capital and skilled labor in their total income mix than the low-income groups, the former groups gain disproportionally.

Differently speaking, in a policy targeting power supply increment from renaissance dam, the increments in the income of poor and non poor households in rural and urban areas are different. For instance, in our policy shocks, the nominal income is slightly lower for rural households particularly for rural poor households than urban ones. For rural households, labor income is lower due to lower agricultural labor returns in rural area while capital income is lower as it is affected by a lower return to agricultural land in rural area. As share however; agricultural labor income is an important source of income for the rural low income households representing 86 percent of total income and 45 percent of the total income for the rural rich ones. Conversely, in opting of our policy shock urban households see their income rises compared with the baseline scenario. This can be illuminated with the fact that non-agricultural labor and capital, in which they are highly endowed, have higher returns in urban area compared rural one in all simulation periods as we have seen in section 4.2.3 above.

Figure4.7: The effect of GERD on household income (% change with respect to baseline scenario)



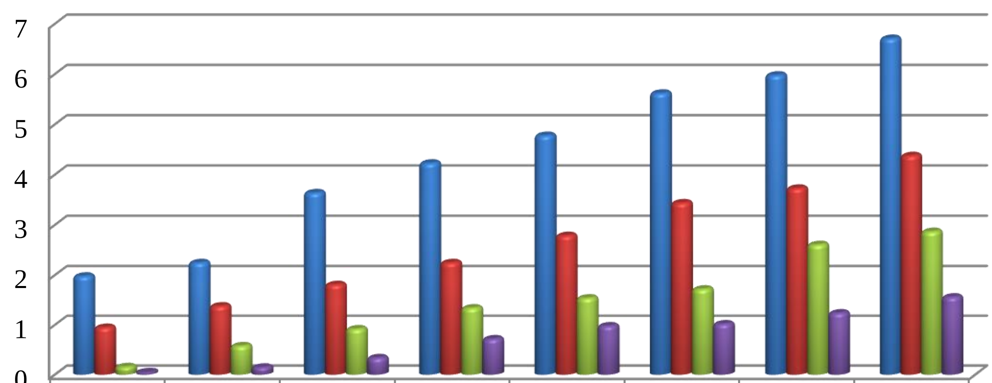
	2018	2019	2020	2021	2022	2023	2024	2025
Urban Rich	2.86	3.28	4.62	5.08	6.74	7.65	8.69	8.76
Urban Poor	1.25	1.82	3.01	3.57	4.75	5.82	7.03	8.38
Rural Rich	1.04	1.36	2.23	2.54	3.59	4.24	5.81	6.87
Rural Poor	0.45	0.62	1.26	1.47	1.98	2.52	2.84	3.41

Source: GAMS result and Author's Own Calculations

4.2.6. Effect on Households Consumption Expenditure

On household's consumption expenditure side, in our model we have assumed that households spend their income on consumption after they pay taxes, save and transfer to other institutions. Hence, additional power supplies from Ethiopian renaissance dam affect the consumption expenditure of households by altering household's consumption. In our policy shock, we have aggregated households in to poor and non poor both in urban and rural areas. In consequence, with additional power supplies from renaissance dam the growth rate of households consumption expenditure of both poor and non poor households in both urban and rural areas has recorded a positive growth rate compared to the base line simulation. However, as can be seen from figure 4.7 below the increments in growth rate of consumption expenditures of poor and non poor households in rural and urban areas are different. For instance, the consumption expenditure of urban poor and rich households has increased by 1.98 and 0.95 percent in 2018, by 4.23 and 2.25 percent in 2021 and by 6.71 and 4.38 percent in 2025 compared to the baseline scenario, respectively. The consumption expenditure of rural rich and poor households has also increased by 0.16 and 0.05 percent in 2018, by 1.34 and 0.72 percent in 2021 and by 2.87 and 1.56 percent in 2025 compared with the reference scenario, respectively.

Figure4.8 *The effect of GERD on household's consumption expenditure (% change with respect to baseline scenario)*



	2018	2019	2020	2021	2022	2023	2024	2025
Urban Rich	1.98	2.25	3.64	4.23	4.78	5.62	5.98	6.71
Urban Poor	0.95	1.38	1.81	2.25	2.79	3.44	3.73	4.38
Rural Rich	0.16	0.58	0.92	1.34	1.54	1.72	2.61	2.87
Rural Poor	0.05	0.15	0.34	0.72	0.98	1.02	1.24	1.56

Source: GAMS result and Author's Own Calculations

If we look this memo in another sight, we have observed that rural households allocate lower share of their consumption expenditure to electricity in their expenditure mix and, therefore; benefit relatively lower than other categories of households from lower prices of electricity and its supply increment. Moreover; if we looked at the effect at more disaggregated level the rich urban households benefit relatively higher than the poor urban one in consumption expenditure. Symmetrically, in the rural area, the rural poor households benefit relatively less than the rural rich households. These results are not surprising since wealthier households consume more electricity in many more ways compared to poorer ones, whose electricity consumption is limited mainly to lighting. Obviously, households can accrue electrification benefits through multiple channels (e.g., extended hours of business operation, growth of businesses that use electricity for production purposes, and exposure to television and other electronic media). Thus it is clear that richer households can exploit these channels to an extent that poorer ones cannot

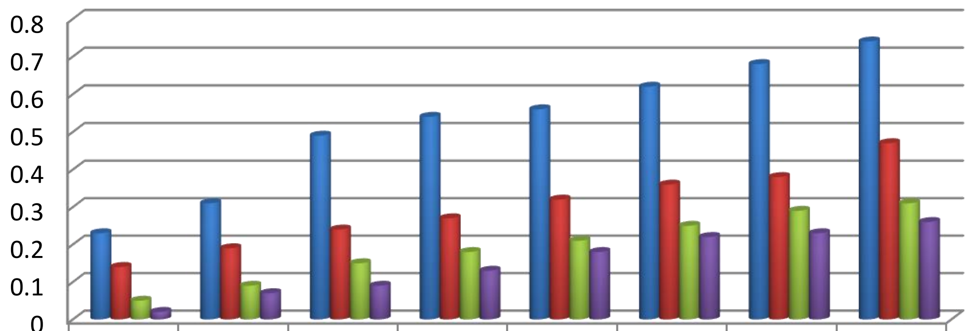
4.1.1. Welfare effect

It is obvious that without changes in the electricity structure, economic and social transformation will lack motivation and the development foundation will be unsustainable. Therefore; its impacts on consumption and hence welfare are paramount. The construction of Ethiopian renaissance dam can affect household welfare through income via changes in factor incomes and through the expenditure via changes in commodity prices (Wiebelt et al., 2015). To examine the impact of the policy simulation on the household's welfare we can use variables like household consumption expenditure and household real consumption. However, in most literature, to measure the welfare impact, equivalent variation (EV) is used as an important tool. EV compares "the costs of pre- and post-shock levels of consumer utility, both valued at base year prices'' (Burfisher, 2011). A positive EV implies a welfare gain due to the new policy/shock: a negative EV indicates welfare loss.

In our experimental simulation the welfare effects of Ethiopian renaissance dam, as measured by the equivalent variation (EV), are substantial. Figure 4.9 below shows the improvements of welfare for all the households but much smaller compared to GDP gains. As we can see from the same diagram the shift in relative income across the household categories favors high income households. This is due to the fact that these households derive most of their income from increased capital earnings and from increased earnings of skilled labor.

Moreover; a power supply increment causes prices to fall in the long run. This is due to the fact that with the rise in electricity supplies, the output of various sectors increase; hence, the supply of various goods increases more than what demand does. This will cause, ceteris paribus, a fall of final internal prices, which are a composite of prices of imports and domestically produced commodities. This reduction in price will in turn increase the purchasing of the households. Consequently, household's spending habits changed and Ethiopian economy experiences a positive welfare change in opting of our policy changes.

Figure4.9: GERD effect on household's welfare (Variation from its baseline scenario)



	2018	2019	2020	2021	2022	2023	2024	2025
Urban Rich	0.23	0.31	0.49	0.54	0.56	0.62	0.68	0.74
Urban Poor	0.14	0.19	0.24	0.27	0.32	0.36	0.38	0.47
Rural Rich	0.05	0.09	0.15	0.18	0.21	0.25	0.29	0.31
Rural Poor	0.02	0.07	0.09	0.13	0.18	0.22	0.23	0.26

Source: GAMS result and Author's Own Calculations

5. Conclusion and Recommendation

5.1.Conclusion

To examine the economy wide effect of Ethiopian renaissance dam on Ethiopian economy**,** this model used an updated Social Accounting Matrix for 2009/10 by outlined a recursive dynamic computable general equilibrium approach. The economy-wide nature of the CGE model that we have developed in this paper will gives us a detailed picture of the role which renaissance dam expected to play on Ethiopian economy over the coming years. Hence, in this study we uses the change in real GDP, sectors production, investment, external sector, household income and consumption expenditures, and household's welfare relative to the baseline, as an indicators of the economic wide effects of the renaissance dam.

In opting for our policy shock, the results of exercise showed that with an increment in power supply the country can optimize the beneficial impacts on its economy. Specifically the simulation results show a spreading out effect in real GDP, sectors output, real investment, household income and consumption expenditure. In our experimental simulation, GDP gain accelerates with an additional power supplies resulted from Ethiopian renaissance dam, i.e. on average Ethiopian GDP grows by 2.29 from the year 2018 to 2025 compared to the baseline scenario.

Regarding to employment, the construction of Ethiopian renaissance dam through supplying additional power has a positive impact almost in all sectors without altering the economic wide wage rates. More specifically, in opting of our policy shock with additional power supplies from renaissance dam skilled workers employment grows most in the manufacturing and industry sectors, semi skilled workers employment grows most in services sectors, and unskilled workers employment grows most in agriculture sector. With the rise in production and productivity almost in all sectors, in our exercise workers see their returns to rise. Besides, the impacts of Ethiopian renaissance dam via supplying additional power supply on sectors production are also fairly positive for almost all the sectors as the construction of Ethiopian renaissance dam benefits all sectors through a reduction in margin costs.

Our results also showed the improvement in the welfare for all the households' categories. However; the shift in relative income across the household categories favors high income households. This is due to the fact that these households derive most of their income from increased capital earnings and from increased earnings of skilled labor. As well, high-income groups have higher shares of capital and skilled labor in their total income mix than the low-income groups, the former groups gain disproportionally. Overall, this paper suggests that Ethiopian economy enjoys the largest improvement in household income and hence consumption expenditures with the construction of Ethiopian renaissance dam.

5.2. Recommendation

In the backstop of the above mentioned results, this study comes out with the following recommendations:

- Under the background of a long-term power supply from the Ethiopian renaissance dam, industries transfer to high power-consuming sectors from low power consuming one. Hence; the government should ensure adequate power generation to meet the industrial electricity demand and to avoid the adverse effects of electrical power shortages on industrial production.
- As production and productivity of industrial sector improves more following the construction of Ethiopian renaissance dam shock, Ethiopian government should speed up the adjustment of industrial structure. This is also necessary to increase the proportion of service industry to GDP and employment creation.
- At the same time, national policy makers should give special emphasis on the construction of Ethiopian renaissance dam as additional power supply from GERD makes the output of almost every sector increases and Ethiopian economy experiences a positive welfare change in opting of our policy changes.
- Lastly, in terms of future research, this paper only considered the economic impact of the construction of Ethiopian renaissance dam; further research is required to get a more holistic view on the impact of Ethiopian renaissance dam on the environment and social considerations. Consequently, alongside policy options that can spur greater employment and economic growth by reducing the cost of adopting environment friendly energy strategies will append attention in the theme.

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Appendix A: Mathematical Summary Statement for CGE model (Lofgren et al., 2002**)**

SETS			
$\alpha \epsilon A$	Activities	$\subset CMR(\subset C)$	Regionally imported commodities
$\alpha \epsilon ACES(\subset A)$	Activities with CES function between Value Added and Intermediate inputs	$f \in FCAP((\subset F)$	Capital Factors
$\alpha \epsilon ALEO((\subset A)$	Activities with Leontief technology between Value added and intermediate	$f \in FCAPGOV((\subset FCAP)g$	Government capital factors
$c \in C$	commodities	$f \in FEXOG(\subset F)$	Factors with exogenous growth rates
$c \in CD(\subset C)$	Commodities with domestic sales of domestic output	$i \in INS$	Institutions(domestic and the rest of the world)
$c \in CDN(\subset C)$	Commodities not in *CD*	$i \in INSD(\subset INS)$	Domestic institutions
$c \epsilon CE(\subset C)$	Exported commodities	$i \in INSDNG(\subset INSD)$	Domestic nongovernment institutions
$c \in CEN(\subset C)$	Commodities not in *CE*	$h \in H(\subset INSDNG)$	Households
$c \in CM(\subset C)$	Aggregate imported commodities		
$c \in CMN(\subset C)$	Commodities not in *CM*		

PARAMETERS

Latin letters			
$cwts_c$	Weight of commodity c in the CPI	pwm_c	Import price (foreign currency)
$dwts_c$	Weight of commodity c in the producer price index	$pwmr_{cr}$	Import price by region (foreign currency)

ica_{ca}	Quantity of c as intermediate input per unit of activity a	$qdst_c$	Quantity of stock change
$icd_{cc'}$	Quantity of commodity c as trade input per unit of c' produced and sold domestically	$\overline{qg_c}$	Base-year quantity of government demand
$ice_{cc'}$	Quantity of commodity c as trade input per exported unit of c'	$\overline{qinv}$	Base-year quantity of private investment demand
$icer_{c\,c'r}$	Quantity of commodity c as trade input per exported unit of c' from region r	$shif_{if}$	Share for domestic institution i in income of factor f
$icm_{cc'}$	Quantity of commodity c as trade input per imported unit of c'	$shii_{ii}$	Share of net income of i' to i($i' \in INSDING'$; i ∈INSDNG)
$icmr_{c\,c'r}$	Quantity of commodity c as trade input per imported unit of c' from region r	ta_a	Tax rate for activity a
$inta_a$	Quantity of aggregate intermediate input per activity unit	$\overline{tins_i}$	Exogenous direct tax rate for domestic institution i
iva_a	Quantity of aggregate intermediate input per activity unit	tm_c	Import tariff rate

$\overline{mps}_i$	Base savings rate for domestic institution i	tq_c	Rate of sales tax
pwe_c	Export price (foreign currency)	$trnsfr_{i\,f}$	Transfer from factor f to institution i
$pwer_{cr}$	Export price by region (foreign currency)	tva_a	Rate of value-added tax for activity *a*

Greek Letters

α_α^α	Efficiency parameter in the CES activity function	δ_c^t	CET function share parameter
α_α^{va}	Efficiency parameter in the CES value added function	δ_{fa}^{va}	CES value-added function share parameter for factor f in activity a
α_α^{ac}	Shift parameter for domestic commodity aggregation function	γ_{ch}^m	Subsistence consumption of marketed commodity c for household h
α_α^q	Armington function shift parameter	θ_{ac}	Yield of output c per unit of activity a
α_α^t	CET function shift parameter	ρ_α^α	CES production function exponent
α_c^m	Shift parameter in the CES regional import function	ρ_a^{va}	CES value-added function exponent
α_c^e	Shift parameter in the CES regional export function	$\rho_c^{\alpha c}$	Domestic commodity aggregation function exponent
β_{ach}^h	marginal share of consumption spending on home commodity c from activity a for household h	ρ_c^q	Armington function exponent

B_{ch}^{m}	Marginal share of consumption spending on marketed commodity	ρ_c^t	CET function exponent
δ_α^α	CES activity function share parameter	δ_c^α	Armington function share parameter
$\delta_{\alpha c}^{\alpha c}$	Share parameter for domestic commodity aggregation function	δ_t	Capital depreciation rate
Exogenous Parameters			
$\overline{CPI}$	Consumer price index		
$\overline{DTINS}$	Change in domestic institution tax share (= 0 for base; exogenous variable)	$\overline{MPSADJ}$	Savings rate scaling factor (= 0 for base)
$\overline{FSAV}$	Foreign savings (FCU)	$\overline{WF_f}$	Average price of factor
$\overline{GADJ}$	Government consumption adjustment factor	$\overline{TINSADJ}$	Direct tax scaling factor (= 0 for base; exogenous variable)
$\overline{IADJ}$	Investment adjustment factor	$\overline{WFDIST}_{fa}$	Wage distortion factor for factor f in activity a
Endogenous Parameters			
AWF_{ft}^{a}	Average capital rental rate in time period t	QF_{fa}	Quantity demanded of factor f from activity a
DPI	Producer price index for domestically marketed output	QG_c	Government consumption demand for commodity
EG	Government expenditures	QH_{ch}	Quantity consumed of commodity c by household h
EH_h	Consumption spending for household	QHA_{ach}	Quantity of household home consumption of commodity c from activity a for household h
EXR	Exchange rate (LCU per unit of FCU)	$QINTA_a$	Quantity of aggregate intermediate input

GOVSHR	Government consumption share in nominal absorption	$QINT_{ca}$	Quantity of commodity c as intermediate input to activity a
GSAV	Government savings	$QINV_c$	Quantity of investment demand for commodity
INVSHR	Investment share in nominal absorption	QM_c	Quantity of imports of commodity c
MPS_i	Marginal propensity to save for domestic non-government institution (exogenousvariable)	QQ_c	Quantity of goods supplied to domestic market (composite supply)
PA_a	Activity price (unit gross revenue)	QT_c	Quantity of commodity demanded as trade input
PDD_c	Demand price for commodity produced and sold domestically	QVA_a	Quantity of (aggregate) value added
PDS_c	Supply price for commodity produced and sold domestically	QX_c	Aggregated quantity of domestic output of commodity
PE_c	Export price (domestic currency)	$QXAC_{ac}$	Quantity of output of commodity c from activity a
$PINTA_a$	Aggregate intermediate input price for activity a	$TINS_i$	Direct tax rate for institution i ($i \subset$ INSDNG)
PM_c	Import price (domestic currency)	$TRII_{ii'}$	Transfers from institution i' to i (both in the set INSDNG)
PQ_c	Composite commodity price		
PVA_a	Value-added price (factor income per unit of activity)	YF_f	Income of factor f
PX_c	Aggregate producer price for commodity	YG	Government revenue

$PXAC_{ac}$	Producer price of commodity c for activity a	YI_i	Income of domestic nongovernment institution
QA_a	Quantity (level) of activity	YIF_{if}	Income to domestic institution i from factor f
QD_c	Quantity sold domestically of domestic output	$QSFf$	Quantity supplied of factor
QE_c	Quantity of exports		

Lists of equation

Price Block

$PM_C = Pwm_c.(1 + tm_c).EXR + \sum_{c\prime\epsilon CT} PQ_{C\prime}.icm_{c\prime c}$	Import Price
$PE_c = pwe_c.EXR - \sum_{c'\epsilon CM} PQ_c.ice_{c'c}$	Export Price
$PDD_c = PDS_c + \sum_{c\prime\in CM} PQ_{c\prime}.icd_{c\prime c}$	Demand Price of Domestic Non- traded Goods
$PQ_c.(1 - tq_c).\ QQ_c = PDD_c.QD_c + PM_c.QM_c$	Absorption
$PX_C.QX_C = PDS_C.QD_C + PE_C.QE_C$	Marketed Output Value
$PA_a = \sum_{c\prime\in C} PXAC_{ac}.\theta_{ac}$	Activity Price

$$PINTA_a = \sum_{c'C} PQ_C .\ ica_{c\,a}$$ Aggregate Intermediate Input Price

$$PA_\alpha.(1 - ta_\alpha).QA_\alpha = PVA_a .QVA_a + PINTA_a + QINTA_a$$ Activity Revenue and cost

$$\overline{CPI} = \sum_{C \in C} PQ_c\ .cwts_c$$ Consumer Price Index

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

Production and Trade Blocks

$$QA_\alpha = (\alpha_\alpha^\alpha(\delta_\alpha^\alpha.QVA_\alpha^{-\rho_\alpha^\alpha} + (1-\delta_\alpha^\alpha).QINTA_\alpha^{-\rho_\alpha^\alpha})^{\frac{-1}{P_\alpha^\alpha}}$$ CES Activity Production Function

$$\frac{QVA_\alpha}{QINTA_\alpha} = \left(\frac{PINTA_\alpha}{PVA_\alpha}.\frac{\delta_\alpha^\alpha}{1-\delta_\alpha^\alpha}\right)^{\frac{1}{1+P_\alpha^\alpha}}$$ Value-Added–Intermediate-Input Ratio

$$QVA_a = \alpha_\alpha^{v\alpha}(\delta_{f\,a}^{va} L^{-\rho_a^{va}} + \left(1-\delta_{f\,a}^{va}\right)K^{-\rho_a^{va}})^{\frac{-1}{\rho_a^{va}}}$$ Value-Added and Factor Demands

$$QINTA_\alpha = \quad inta_\alpha \cdot QA_\alpha$$ Demand for Aggregate Intermediate Input

$$QVA_\alpha = iva_\alpha.QA_\alpha$$ Aggregate Value- Added

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

$$QINTA_{ca} = ica_{ca}.QINTA_a$$ Disaggregated Intermediate Input

$$QXAC_{ac} + \sum_{h \in H} QHA_{a\,c\,h} = \theta_{a\,c}.QA_a$$ Commodity Production and Allocation

$$QX_c = a_c^{ac}(\sum_{a \in A} \delta_{a\,c}^{ac}.QAC_{a\,c}^{-\rho_c^{ac}})^{-\frac{1}{\rho_c^{ac}-1}}$$ Output Aggregation Function

$$PXAC_{a\,c} = PX_cQX_c\left(\sum_{a \in A'} \delta_{a\,c}^{ac}.QXAC_{a\,c}^{-\rho_c^{ac}}\right)^{-1}.\delta_{a\,c}^{ac}.QXAC_{a\,c}^{-\rho_c^{ac}-1}$$ First-Order Condition for Output Aggregation Function

$$QX_c = a_c^t.\left(\delta_c^t.QE_c^{pc^t} + (1-\delta_c^t).QD_c^{pc^t}\right)^{\frac{1}{pc^t}}$$ Output Transformation (CET) Function

$$\frac{QE_C}{DD_C} = \left(\frac{PE_C}{PDS_C} - \frac{1-\delta_c^t}{\delta_c^t}\right)^{\frac{1}{\rho_c^t - 1}}$$	Export-Domestic Supply Ratio
$$\frac{QM_C}{QD_C} = \left(\frac{PDD_C}{PM_C} - \frac{1-\delta_c^q}{\delta_c^q}\right)^{\frac{1}{1+\rho_c^q}}$$	Import-Domestic Demand Ratio
$$QQ_C = a_c^q \left(\delta_c^q . QM_c^{-p_c^q} + (1-\delta_c^q). QD_c^{-p_c^q}\right)^{-\frac{1}{P_c^q}}$$	Composite Supply (Armington) Function
$$QX_c = a_c^t.\left(\delta_c^t . QE_c^{pc^t} + (1-\delta_c^t). QD_c^{pc^t}\right)^{\frac{1}{pc^t}}$$	Output Transformation (CET) Function
$$QQ_C = QDc + QMc$$	Composite Supply for Non-imported Outputs and Non produced Imports
$$QX_C = QDc + QEc$$	Output Transformation for Domestically Sold Outputs Without Exports and for Exports Without Domestic Sales

Institutional block

$$YF_f = \sum_{a \in A} \overline{WF_f} . \overline{WFDIST_{f\,a}} . QF_{f\,a}$$	Factor income
$$YIF_{i\,f} = shif_{i\,f}.\left[(1-tf_f).YF_{f\_}trnsfr_{row\,f}.EXR\right]$$	Institutional factor income
$$YI_i = \sum_{f \in F} YIF_{i\,f} + \sum_{i' \in} TRII_{i\,i'} + trnsfr_{i\,gov}.\overline{CPI} + trnsfer_{\,i\,row} . EXR$$	Income of domestic, Nongovernment Institutions
$$TRII_{i\,i'} = shii_{\,i\,i'}.(1-MPS_{i'}).(1-TINS_{i'}).YI_{i'}$$	Intra-Institutional Transfers
$$EH_h = \left(1 - \sum_{i \in INSDING} shii_{i\,h}\right).(1-MPS_h).(1 - TINS_h).YI_h$$	Household consumption expenditures
$$PQ_cQH_{C\,h} = PQ_c.\gamma_{c\,h}^m + \beta_{c\,h}^m.\left(EH_h - \sum_{c' \in C} PQ_{c'}.\gamma_{C'\,h}^m - \sum_{a \in A}\sum_{C' \in C} PXAC_{a\,c'}.\gamma_{a\,c'h}^h\right)$$	Household Consumption Spending on Marketed Commodities

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

Household spending on home commodities

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

Investment demand

$$QG_C = \overline{GADJ}.\overline{qg}_C$$

Government consumption demand

$$YG = \sum_{i' \in INSDING} TINS_i\,.\,YI_i + \sum_{f \in F} tf_f\,.\,YF_f + \sum_{a \in A} tva_a.PVA_a.QVA_a + \sum_{a \in A} ta_\alpha\,.\,PA_a.QA_a + \sum_{a \in CM} tm_C\ .\,pwm_C.QM_C.EXR + \sum_{c \in CE} te_C + pwe_C.QE_C.EXR + \sum_{c \in C} tq_c.PQ_C.QQ_C + \sum_{f \in F} YIF_{gov\,f} + trnsfr_{gov\,row}.EXR$$

Government revenue

$$EG = \Sigma PQc.QGc + \Sigma trnsfri\ gov\,.\,\overline{CPI}$$

Government expenditure

System Constraints and Closures

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

Factor markets

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

Composite Commodity Markets

$$\sum_{c\in CM} pwm_c.QM_c + \sum_{f\in F} transfr_{row\ f} = \sum_{C\in CE} pwe_c.QE_c + \sum_{i\in INSD} transfr_{i\ row} + \overline{FSAV}$$

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

$$YG = EG + GSAV$$

Government Balance

$$TINSi = \overline{tinsi}\,.(1 + \overline{TINSADJ}.tins01i) + \overline{DTINS}.tins01i$$

Direct institutional tax rate

$$MPSi = \overline{mpsi}\,.(1 + \overline{MPSADJ}.mps01i) + DMPS.mps01i$$

Institutional saving rate

$$\Sigma MPSii \in INSDNG(1 - TINSi).YIi + GSAV + EXR.\overline{FSAV} = \Sigma PQc\,.QINVc + \Sigma PQc\,.qdstc$$

Saving –investment balance

$$TABS = \Sigma\Sigma(PQcQHch)c\epsilon Ch\epsilon H + \Sigma\Sigma\Sigma(PXACacQHAach)h\epsilon Hc\epsilon Ca\epsilon A + \Sigma PQc.QGcc\epsilon C + \Sigma PQc\,.QINVc\ c \in C + \Sigma PQc\,.qdstc$$

Total absorption

$$INVSHR.TABS = \Sigma PQc\,.QINVc + \Sigma PQc\,.qdstc$$

Ratio of investment to absorption

$$OVSHR.TABS = \Sigma PQc.QGc$$

Ratio of government consumption to absorption

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

Average capital rental rate

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

Share of new capital

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

Quantity of new capital by sector

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

Unit price of capital

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

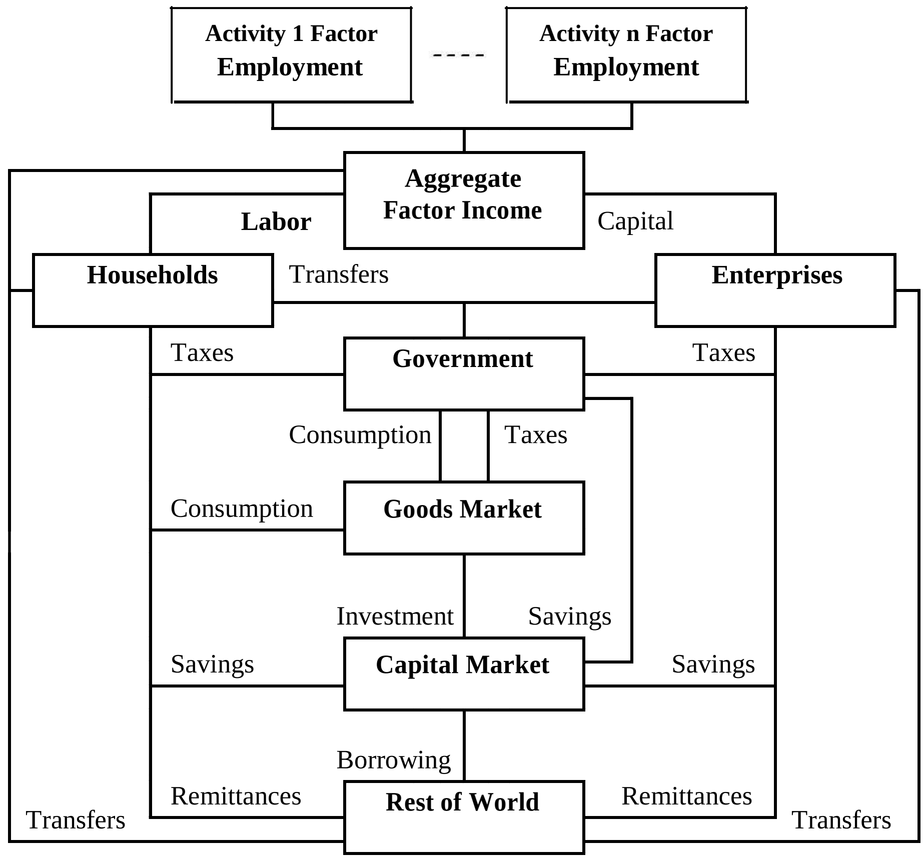
Average Price of capital

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

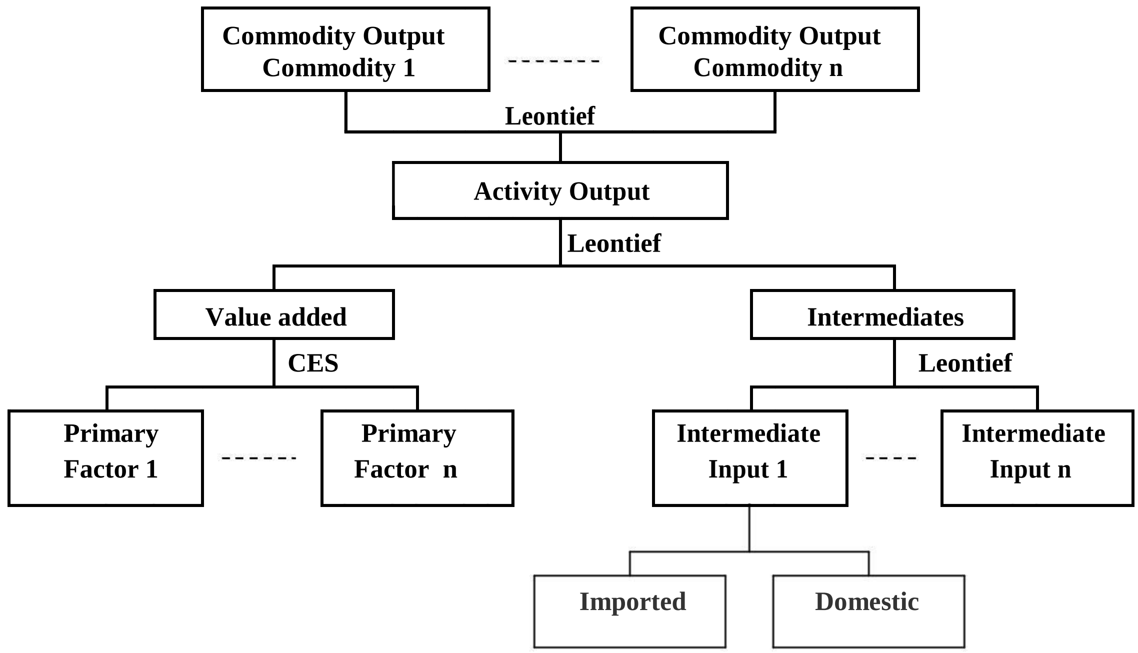
$$RWF_{ft} = RWFft - 1(1 + \varpi)$$

Real wage updating equation

Appendix B: Institutional Incomes flows and Domestic Demand



Appendix C: Production Technology



Appendix D: Flows of commodities in the markets