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GRAND ETHIOPIAN RENAISSANCE DAM: A GLOBAL CGE MODEL TO ASSESS THE ECONOMIC EFFECTS ON THE ETHIOPIAN ECONOMY

EMANUELE FERRARI^{*} , SCOTT McDONALD^{*} , REHAB OSMAN^{*}

^{*} Oxford Brookes University
Department of Accounting, Finance and Economics – Faculty of Business

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Address for correspondence:
Emanuele Ferrari
Business School
Department of Accounting, Finance and Economics
Oxford Brookes University
Wheatley Campus
Oxford
OX33 1HX
Email: eferrari@brookes.ac.uk
Tel: +44 (0)1865 485671

Abstract

The Grand Ethiopian Renaissance DAM (GERD) will become the largest dam and hydroelectric scheme in Africa; it is also one of the world's most controversial dam projects and one of four large scale hydropower projects currently under construction in Ethiopia. Ethiopia's endowment of water resources, with its 12 major river basins, is impressive but its potential to exploit is scarcely developed (AQUASTAT, 2005). It is estimated that over 85% of the Nile waters and sediment reaching Egypt originate from the Ethiopian highlands. Nevertheless the 1959 Nile Waters Treaty, between Egypt and Sudan, allocated well over 95% of the estimated available Nile waters to Egypt (75%) and Sudan (25%) thereby leaving very little to the other 8 states in the Nile basin. This study uses a variant of the GLOBE_EN, extended by segmenting the electricity generating sector between hydro and fossil fuel powered electricity generating sections in Ethiopia, Egypt and Rest of Eastern Africa (that includes Sudan). The simulations are conducted using the recursive dynamic variant of the GLOBE_EN model. Preliminary results indicate that GERD investments would slow down development in Ethiopia and that the exports of hydroelectricity need to expand rapidly straight after the completion of GERD if the project is to be successful.

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1. Introduction

According to the Ethiopian government, potential hydro capacity of the country exceeds 45,000MW. This great potential is mainly attributed to the huge surface water resources flow from highlands. Despite such potential, the majority of Ethiopians has no access to electricity or experiences energy insecurity. In addition, the use of traditional fuels, e.g. fire wood, to produce energy aggravates the issues of soil erosion and forest destruction.

Despite the increasing public investments, the current utilization of hydropower resources is limited to 2,000 MW which is less than 4.5% of the estimated hydropower potential. Effective development and management of hydropower is central for sustainable development and economic growth of the country. The government has embarked in energy production development projects by constructing various hydropower plants. Amongst is the Grand Ethiopian Renaissance Dam (GERD) project. GERD is anticipated to be the biggest hydroelectric power project in Africa with a planned installed capacity of 6,000 MW and 15,128 GW annual. The project would satisfy the increasing domestic demand for electricity and provide reliable hydropower supply, which are part of support the country's Universal Electrification Access Program. Besides, GERD project would enable Ethiopia to export power through regional interconnection system. In addition to foreign currency earnings, exporting electricity to the neighbouring countries would enhance the country's economic integration in the region . Nevertheless, exports increase could cause the typical Dutch disease effect; i.e. appreciation of real exchange rate, which can lead to shrinkage in the current exporting sectors. Given that Ethiopia main exports are agricultural commodities, agricultural may be negatively affect and consequently the poorer part of the Ethiopian population may suffer negative outcomes.

Ethiopia has great potentials to develop its water resources since the country is richly endowed with 12 major river basins, even if scarcely developed (AQUASTAT, 2005). Hydropower and irrigation are the two main future uses of these potential water resources. This paper considers the issue of energy production from hydropower. It does not deal with other related issues like irrigation development and distributing Nile water among other riparian states.

The sustained growth of the Ethiopian economy (on average the GDP grew 10% annually between 2004 and 2011 (WDI, 2012)) and the subsequent increased in demand for energy input is emphasizing the lack of power creation capacity in the country. In the past years, the Ethiopian Electric Power Corporation (EEPco) had to rationalize power supply once or twice a week as immediate solution to power shortage (Engida, Eyasu, & Seneshaw , 2011). This energy rationing policy adversely affected many industrial sectors and obstructed the economy-wide growth.

Currently, 87% of the electricity production comes from hydroelectric sources while the remaining 13% is generated from oil . Out of the 30372.986 thousand tonnes of oil equivalent (ktoe) on a net calorific value basis, around 7% of energy is imported. In order to meet the increasing demand for electricity by the growing Ethiopian economy, , the government launched a plan to exploit the electricity generation potentials in the country. The government has adopted additional five hydroelectric dams and one wind farm. These projects would magnify power supply from 2,000MW to 3,270 MW and provide electricity access to 50% of the Ethiopian households. In addition, the dams would regulate water flows, control floods, and channel water for irrigation purposes (World Bank, 2010).

The potential expansion of hydropower electricity generation, through the constructions of new dams, might yield favourable effects in the economy. The sustainable increase in domestic demand for power supports the expansion of Ethiopia's hydropower sector. In addition, with possible expansion of foreign demand, Ethiopia has a great opportunity to become a net electricity exporter, which in turn strongly accelerates the country's economic growth. According to the World Bank (2010): "strengthened hydropower development can both increase near term economic growth and make the energy system more climate resilient. More reservoir storage distributed over the country would provide more reliability and protection from regional droughts". The related water issues, such as the potential effects on the Ethiopian agriculture as a result of better control of floods and droughts and the possible consequences of constructing the dam on the two downstream riparian countries (i.e. Egypt and Sudan), requires more detailed analysis which goes beyond the scope of this paper.

Among the financed projects (

Table 1), the most ambitious one is the construction of the Grand Ethiopian Renaissance Dam (formerly known as Millennium dam). Launched on April 2nd 2011, by the Ethiopian Prime Minister Meles Zenawi, the dam is the biggest hydroelectric power project in Africa with an installed capacity of 6,000 MW and 15,128 GW annual energy. The dam is currently under construction and is anticipated to be completed in 44 months. The dam is built on the Blue Nile River, in the western part of Ethiopia about 40 kilometres from Sudan's border. The government reports that the project costs \$4.8 billion; around 15% of the Ethiopian GDP. According to former Prime Minister Zenawi, the construction of the dam can be completed without any foreign aid. The Economist (2011) reports that Chinese banks are underwriting the cost of turbines and other electrical equipment. Yet, this means that there is need to cover a financial gap of \$3 billion of establishment investment. Not to mention that some engineers believe that the construction cost is much higher than the government estimation. Ethiopians are urged to subscribe to bonds issued on patriotic grounds. This, however, would not generate more than a small fraction of the required fund. Neither the World Bank nor private investors are willing to contribute, since Ethiopia has failed to establish partnership ties with the power generating companies in neighbouring countries, who are the future consumers of the Dam's electricity (The Economist, 2011).

The reservoir capacity of the dam is roughly equivalent to the annual flow of the Nile water at the Sudanese-Egyptian border (65.5 billion cubic meters). This loss to the downstream countries' water share would take place only over the reservoir filling period. However, this water loss might continue to induce noticeable long term effects on the downstream countries. Evaporative losses from the dam's reservoir would permanently reduce the flow of the Blue Nile. The magnitude of these losses is not accurately estimated yet. The three Eastern Nile Countries (Egypt, Ethiopia, and Sudan) have formed an International Panel of Experts to review and assess the potential effects of the Ethiopian Great Renaissance Dam on the Blue Nile. In his speech at the official commencement of the Millennium Dam project, the former Ethiopian PM has assured that the dam will greatly reduce the problems of silt and sediment that have been consistently affecting the dams in Egypt and Sudan and that communities along the riverbanks in Sudan will be permanently relieved from centuries of flooding. In light of these potential benefits from GRED for Egypt and Sudan as well as the Ethiopian offer to export electricity at a price lower than the world price, Zenawi has demanded for their contribution to the project costs (according to his calculation, Sudan might offer to cover 30 per cent

and Egypt 20 per cent) even if he recognized that the current political climate does not allow to reach this agreement.

In addition, the construction of the dam and the creation of new electricity potential would strengthen the Eastern Africa Power Pool (EAPP), created in 2005 by seven Eastern Africa countries (Burundi, Democratic Republic of Congo (DRC), Egypt, Ethiopia, Kenya, Rwanda and Sudan) which recognized as the potential benefits from developing a regional power pool. The mission of the EAPP is secure an affordable, sustainable and reliable source of electricity for the Eastern Africa region by the pooling of electrical energy resources in coordinated and optimized manner with an ultimate goal of increase the rate of access to electricity in the region and thereby promoting regional integration. Other objectives include optimizing the usage of energy resources available in the region, increase power supply in the region, reduce electricity production cost and create attractive investment climate.

This study aims at analysing the possible economic effects of GRED on the Ethiopian economy, the Nile basin Ethiopian neighbours and the rest of the world. The study uses a global Computable General equilibrium model with a focus on energy issue; GLOBE-E. The rest of the paper is organized as follows: Sections 2 provides a brief literature review of the main issues under consideration. Sections 3 presents the employed model, and the underlying database and its aggregation. Section 4 describes the simulation scenarios and the simulation results. Section 5 discusses the policy implications. Section 6 concludes.

2. Literature review

The issue of energy production, in particular in his relationship with climate change and climate policy, has been extensively analysed in the CGE literature. Several CGE models analysed the issue of electricity generation and its link with hydropower. Some of the relevant studies are: the development a dynamic, multisectoral and applied general equilibrium model of the Turkish economy (Aydin, 2010), for Taiwan (Shih-Hsun , Ping-Cheng, & Chung-Huang, 2000) or Russia (Orlov , Grethe, & McDonald, 2011). Most of these studies employ the so called technology bundle to model electricity generation from different sources (ABARE , 1996), in their attempt to increase realism of the model and reconcile top-down models with typical characteristics of bottom-up energy models.

In addition, a similar study is related to the value of the high Aswan dam in Egypt (Strzepek, Yohe, Tol, & Rosegrant, 2008) where the authors employed an extended version of the IFPRI standard static single-country CGE model (Lofgren, Hariss, & Robinson, 2001).

These models are single-country approach to the issue of hydropower. In this paper, we want to address multicounty issue as the trade of electricity or the impact on the exchange rate and on Ethiopian export of the dam construction. For this reason we use an extensively modified version of the global CGE model GLOBE (McDonald, Thierfelder, & Robinson, 2007).

3. The model and the database

The GTAP database version 8 (Narayanan, Aguiar, & McDougall, 2012) boasts 129 regions and 57 sectors for the years 2004 and 2007. In this study, the database for the year 2007 has been aggregated into 28 sectors and 15 regions (Table 2). Among the regions, all the Nile basin countries

have been considered as disaggregated as possible: Egypt, Ethiopia, Kenya, Tanzania, Uganda, South central Africa countries (Angola and Democratic Republic of Congo) and Rest of Eastern Africa (Sudan among others). In addition, main trade partners of the region have been selected: USA, the EU (with 27 member states), China, India, Japan, rest of Africa, rest of Asia while all the remaining countries have been aggregated into a rest of the world (row) region. In terms of activities and commodities, rice, wheat, vegetable and fruit, sugar cane and beet, plant fibres, other crops and livestock represent the primary agricultural sector. The aggregation of the fish and forestry sectors and the mineral sector represent the natural resource accounts. In terms of food industries, rice, meat (aggregation of red and white meat), raw sugar, beverages and tobacco and other food sector have been disaggregated. Five manufacture sectors (textile, chemical, metals, electronic and other manufacture), a trade and transportation sector, water and a service sector aggregating all the other service accounts. The energy sectors are: oil, coal, gas, energy, petroleum and coal products and gas manufacture. In addition, the database counts on the usual five production factors: skilled and unskilled labour, agricultural land, natural resources and capital.

The GTAP database has been augmented with data on electricity production from World Development Indicator. This database provides data on electricity production (kWh) and production from different sources: renewable source (excluding hydroelectric), coal, hydroelectric, natural gas, nuclear and oil sources.

In the case of Ethiopia, in 2007 electricity production was of 3547000000 (kWh), more than 95% of which (3385000000 kWh) from hydroelectric sources and the rest from oil sources. The original Ethiopian SAM has been substituted by a new one where electricity is produced by two activities: oil sources and hydroelectric.

3.1 Model Description

The version of GLOBE employed for this paper is a dynamic modified version of the GLOBE_EN CGE model (McDonald & Thierfelder, 2008) which is a development of the GLOBE model (McDonald, Thierfelder, & Robinson, 2007) where the major changes relate to the modelling of production relationships and the recording of taxes on energy use. The GLOBE model is a member of the class of multi-country, computable general equilibrium (CGE) models that are descendants of the approach to CGE modeling described by Dervis et al. (1982). The model is a SAM-based CGE model, wherein the SAM serves to identify the agents in the economy and provides the database with which the model is calibrated. The SAM also serves an important organizational role since the groups of agents identified in the SAM structure are also used to define sub-matrices of the SAM for which behavioural relationships need to be defined. The implementation of this model, using the GAMS (General Algebraic Modelling System) software, is a direct descendant and extension of the single-country and multi-country CGE models developed in the late 1980s and early 1990s.

The modelling of trade employs the Armington insight in the form of two-level nests of constant elasticity of substitution (CES) functions for imports and two-level nests of constant elasticity of transformation (CET) functions for export.

Final demand by the government and for investment is modelled under the assumption that the relative quantities of each commodity demand by these two institutions is fixed. For the household the model contains the assumption that households are utility maximisers and the utility functions

for private households are assumed to be Stone Geary functions. The utility functions have been altered so that carbon emission taxes can enter into the first-order conditions determining the use of energy commodities by households.

Production relationships by activities are defined as nested Constant Elasticity of Substitution (CES) production functions. Activity output is a CES aggregate of the quantities of aggregate intermediate inputs and aggregate value added, while aggregate intermediate inputs are a Leontief aggregate of the (individual) intermediate inputs and aggregate value added is a CES aggregate of the quantities of primary inputs demanded by each activity. Producers are assumed to maximize profits, which determines product supply and factor demand. Product markets are assumed to be competitive, and the model solves for equilibrium prices that clear the markets. The production system is set up as a multi stage nest of CES production functions.

At the top level aggregate non-energy intermediate inputs (QINT) are combined with aggregate of primary and energy inputs (QVAE) to produce the output of an activity (QX) using a standard CES function. The second level aggregate of non-energy intermediate inputs is a Leontief aggregation of the non-energy intermediate inputs. The value added-energy aggregate (QVAE) is standard CES function of aggregates of capital-energy (QKE) and other (non-capital) primary inputs (QVA).

The value added (QVA) production function is a CES function over labour (which is a CES aggregation between skilled and unskilled labour), land and natural resources, with the elasticities being activity and region specific. The capital-energy aggregate (QKE) is a two argument CES function of aggregate of energy (QVE) and capital and because one of the arguments is a 'natural' inputs the issue of the conditions for factor market clearing become relevant.

The fourth and fifth levels of the production nest distinguish between electricity and other energy inputs where the other energy inputs are directly based on fossil fuels; an important reason for this distinction is the use of fossil fuels in the generation of electricity. At the fourth level aggregate energy (QVE) is defined by a standard CES function over two arguments – electricity and an aggregate of other energy inputs - with the elasticities being activity and region specific. And finally at the fifth level the aggregate of non-electricity inputs is defined by a multi argument CES function over non electricity energy inputs (typically oil, coal, gas, petroleum and gas manufacture).

Factor markets in developed countries are also assumed to have fixed labour supplies, and the model solves for equilibrium wages that clear the markets. In developing countries, however, we assume that the real wage of unskilled labour is fixed and that the supply of unskilled labour is infinitely elastic at that wage. So, labour supply clears the market, and aggregate unskilled employment is endogenous rather than the real wage. In this specification, any shock that would otherwise increase the equilibrium wage will instead lead to increased employment.

In the original GLOBE model the relationship between activity and commodity output is defined as a simple linear relationship whereby the commodity output is defined as the weighted sum of the quantities of each commodity produced by each activity. But given the typical configuration of the GTAP database, whereby each activity only produces a single commodity, domestic output by activity (QX) is identical to domestic commodity output (QXC) and the matrix of weight is a simple identity matrix. To adapt the model the data development (introduction of different activities producing the same commodities, i.e. electricity), we have two options which depend on the level of

homogeneity of the commodities produced. If different activities produce heterogeneous commodities, we employ a Constant Elasticity of Substitution (CES) function which allows imperfect substitutability among commodities, once provided an exogenously given elasticity of substitution. In case the commodities produced are homogenous, we aggregate the production of different activities by a simple summation while the producer price of the composite domestic output is equal to the activity commodity prices (in the case of CES, the prices are given by the CES first order condition). When commodities are homogenous, all the production is rapidly absorbed by the most efficient activity sector. To avoid this problem in the electricity production sector, the demand of capital for electricity produced by hydro sources is kept constant in the baseline and shocked exogenously in the simulations. This mimics the short-medium run asset fixity of a sector like electricity production where, once physical capital is in place (e.g. an electricity power plant) its mobility is quite reduced given the high costs to adapt the plant to different uses.

3.2 Dynamics and Baseline

In order to reproduce the most likely future developments of the economy in the future, several economic variables are exogenously shocked to build a baseline. The baseline represents the business as usual scenario to which all the policy scenarios will be compared.

To establish a baseline for GLOBE, selected macroeconomic variables are updated each year, using forecasts to 2030 from GTAP (GDyn Data Base; www.gtap.agecon.purdue.edu/databases/Utilities/default.asp). The model is solved in a loop over time periods with annual updates. The following macroeconomic variables are updated for each region: GDP, total investment, the internal balance (fiscal deficit), the external balance (trade deficit), total supply of land, total supply of skilled labour, and total supply of unskilled labour. Baseline projections provide growth rates for GDP, non-capital factor supplies, and investment. Each variable is held constant and assigned a value in each year consistent with the baseline. The external (current account balance) and the internal balance (government budget deficit) are assumed to be a fixed share of GDP over time, maintaining the ratio observed in the base year. For baseline updates, all tax rates are held constant while the nominal exchange rate adjusts to achieve the required external balance. The model is investment driven, with the level of investment by region set to match GTAP forecasts.

In factor markets, the total supply of land, skilled labour, and unskilled labour are held constant and assigned forecast values. The nominal wage adjusts to satisfy equilibrium in these factor markets. Likewise, the total supply of capital is held constant and the nominal payment adjusts. Unlike land and labour, capital levels are not from GTAP forecasts. Instead, capital available each period is determined from private investment and depreciation. However, the closure rule is the same – fix the supply of capital each period at the computed level and allow the nominal wage to adjust. In each period, in each region, demand for commodities used in investment is assumed to be in fixed volumes multiplied by an investment-scaling variable that can accommodate changes in the exogenously determined level of investment and/or changes in the availability of funds for investment. The total value of investment, or gross fixed capital formation, is the sum of investment volumes time prices. The value of new capital by region is a weighted average of the price of the goods used in investment; the weights are each commodity's share in the volume of investment. In the baseline loop experiment, the values from the previous period are the data stored in levels.

These levels are used to compute the new value of the capital available to be assigned in the current period when the model solves.

When GDP by region is set exogenously, total factor productivity by region must be endogenous. Anyway, there are well documented reasons to assume that the rates of sectoral productivity growth differ; for instance it is commonly estimated that agricultural productivity grows faster than productivity in other sectors in each region. In this work we assume that agriculture in all regions experiences productivity gains that are 10% greater than those in other sectors.

4. Scenarios description and results

The policy scenarios will be compared with the result of the baseline run. A first change compared to the baseline is the increase of government savings to internally finance the construction of the GERD dam.

At the same time, the capital endowment of the hydropower electricity production is expanded to mimic the building of the GERD dam. Given the nature of such capital (i.e. a dam), the capital is considered as immobile, without the possibility to move to other sectors.

An additional scenario considers an increase of Ethiopian electricity exports to neighbour countries. Currently Ethiopia is not exporting electricity. According to the Ethiopian former Prime Minister, Ethiopia will earn significant hard-currency (or at least bartering leverage) with its neighbours who import the generated power. The following arrangements have already been made with neighbouring countries to supply electricity. Ethiopia might export 200 MW to Djibouti, which would enable Ethiopia to pay for port usage, 500 MW to Kenya, which would enable Ethiopia to pay for its port usage at Mombasa, and 200 MW to Sudan which would enable Ethiopia to buy fuel oil from Sudan in exchange. In order to simulate a scenario in which Ethiopia becomes a net electricity exporter, we modify the Armington Constant Elasticity of Substitution (CES) demand function of the Nile basin countries which are supposed to import electricity from Ethiopia. Following Philippidis (2010), changes in imports are associated with changes in consumer preference towards different imports origin. This modification allows modelling an increase of demand of Ethiopian electricity by other Nile basin countries (i.e. Sudan or Egypt) without shocking policy instruments as import or export taxes which indirectly modify price of imports.

In the third scenario, the increase of Ethiopian demand for electricity will be simulated on top of the construction of the GERD dam. Main sources of this increase are: the Rural Electrification Access Project, which is a project under the Universal Electrification Access program (UEAP), designed to enable towns and villages to have access to electric supply through low and medium voltage distribution lines. Electrification will eliminate the need for gas butane which is supplied in gas cylinders. For those in countryside, there will be no need for burning wood or kerosene. Another source of increasing demand is the possibility to electrify the transportation system (e.g. the Addis Ababa Light Rail Transport system which is still based on electric power. Its electrification will reduce the dependence on fossil fuel).

From these scenarios, we will analyse results in terms of GDP and welfare for Ethiopia and other Nile Basin countries. Then, we concentrate on change of trade pattern, particularly in Ethiopia, to examine whether the increase of electricity production and export will cause a significant

appreciation of the Ethiopian exchange rate and negatively affect other export, i.e. agriculture. Then, results on production will be presented to analyse which sectors will benefit the most from the increase of energy production and the decrease of energy price. Then we concentrate on production factors. Finally, given the energy and environmental focus of the model, the likely change in country and regional emission due to the increased availability of electricity from hydro source will be taken into account.

5. Results

Preliminary results indicate that GERD investments would slow down development in Ethiopia and that the exports of hydroelectricity need to expand rapidly straight after the completion of GERD if the project is to be successful. As expected the 'Dutch disease' implications are not trivial and are likely to hold back Ethiopian development with adverse effects on rural households.

5.1 Sensitivity analysis

6. Policy Implications

7. Conclusions

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Table 1 Ethiopian dams available and under construction

Stations	Capacity (MW)
Koka	43
Awash II	32
Awash III	32
Finchaa	134
Melka Wakena	153
Tis Abay I	11
Tis Abay II	73
Gilegel Gibe I	184
Dire Dawa	184
Awash 7 killo	184
Tekeze	300
Gilgel Gibe II	420
Beles	460
TOTAL	2,211
Projected	Year of Completion
GERD	6,000 2014
Gibe III	1870 2013
Gilgel Gibe IV	2000 2014
Halele Worabese	440 2014
Chemoga Yeda	278 2013
Genale Dawa III	256 2018
Genale Dawa IV	256 2018
Tekeze II	450 2020
Border	800 - 1,200 2026
Mendaia	2,400 - 2,800 2030
TOTAL	14,750-15,550

Source: (Engida, Eyasu, & Seneshaw , 2011) and (World Bank, 2010)

Table 2 GTAP8 2007 disaggregation

Commodities/Activities	Energy Commodities	Production Factors	Regions
Paddy rice	Oil	Land	Egypt
Wheat other cereal grains	Coal	Unskilled labour	Ethiopia
Vegetables fruit nuts	Gas	Skilled labour	Rest of Eastern Africa
Other Crops	Petroleum, coal products	Capital	DR Congo Angola
Sugar cane sugar beet	Electricity	Natural Resources	Kenya
Plant-based fibres	Gas		Tanzania

manufacture	
Livestock products	Uganda
Fishing and forestry	USA
Minerals	EU-27
Meat products	Japan
Dairy products	China
Sugar	India
Other food products	Rest of Asia
Beverages and tobacco products	Rest of SSA
Textiles wearing and leather	Rest of the World
Chemical and mineral products	
Metals and metal products	
Vehicle electronic equipment	
Other manufactures	
Trade, Construction, Transport & Communication	
Water	
Other Services	

Source: authors elaboration.