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# The economic significance of the Grand Ethiopian Renaissance Dam (GERD) to the Eastern Nile Economies: A CGE modeling approach

**Tewodros Negash (PhD), Tadele Ferede (PhD) and Getachew Diriba (PhD)**

***Policy Working Paper 05/2020***

*August 2020*

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# A Snapshot

Ethiopia still has the second largest energy access deficit in Sub-Saharan Africa (after Nigeria), and the third in the world.[5] About 56 percent of Ethiopia's population still do not have access to modern electricity (MoWIE, 2020). The completion of the Grand Ethiopian Renaissance Dam (GERD) is expected to improve access to electricity for the vast majority of the population as well as stimulate the economy and hence result in improved socioeconomic outcomes.

Employing a multi-region multi-sector computable general equilibrium (CGE) modeling framework, this study estimates the direct and indirect economic and social impacts of GERD on the Eastern Nile economies - Ethiopia, the Sudan and Egypt. In doing so, two scenarios are considered. The first scenario considers the economic significance of the GERD operation to the Eastern Nile economies if the dam is filled and becomes operational in four years. In the second scenario, the economic costs of delaying GERD filling and hence its operation beyond four years is estimated. Results of the two scenarios are presented for each country as well as for the three countries combined (i.e. Eastern Nile basin countries).

The simulation results reveal that GERD operation does stimulate real GDP growth in the Eastern Nile basin if it goes operational in 2024 following a four – year filling period (2020 – 2024). The basin-wide annual gain in real GDP due to GERD operation stands at USD 8.07 billion in 2024 relative to the baseline (2020). Ethiopia benefits a staggering USD 6.79 billon in real GDP due to GERD operation while Sudan and Egypt gain USD 1.11 billion and USD 0.17 billion in real GDP, respectively. Thus, all the Eastern Nile countries benefit from the GERD operation, indicating a win-win outcome.

The study also reveals that Ethiopia's economic growth is expected to increase by about 1.5 percent due to GERD operation. The economic growth in Ethiopia is anchored mainly on tremendous increase in energy supply and capital stock

[5] https://www.worldbank.org/en/news/press-release/2018/03/01/world-bank-supports-ethiopias-endeavors-to-provide-all-citizens-with-access-to-electricity

from the GERD which are expected to improve efficiency and productivity in the economy. The economy of the Sudan expands by 1.2 percent due to GERD operation, mainly due to enhanced capital stock resulting from GERD induced flood damage reduction. Reduced sediment load and hence enhanced power generation in the Sudan's power plants from the GERD operation also stimulates economic growth in the Sudan. With higher benefits in terms of improved water use efficiency, the GERD further improves economic growth in the Sudan. GERD operation also offers Egypt's economy significant benefits in terms of increased water supply due to reduced evaporation loss from the High Aswan Dam (HAD), as well as the opportunity for improving water use efficiency as a result of a more regulated flow of water throughout the year. GERD operation overall enhances Egypt's economy to a certain extent. Thus, accounting for engineering estimates of GERD's potential impact on HAD, the net economy-wide effects, in terms of economic and welfare benefits, are positive for all the Eastern Nile countries, including Egypt. This underscores the fact that the benefits of the GERD shall be seen in the wider economic perspective that takes into account both direct and induced effects of the energy generated from the dam.

However, delaying the operation of the GERD involves large economic costs for the three Easter Nile countries. The total basin-wide loss of delaying the GERD operation from 2024 to 2030 is estimated at USD 29,944 billion, with Ethiopia bearing the overwhelming proportion (82.4 percent) of the loss. In particular, Ethiopia's real GDP gain from the GERD operation would decline successively from USD 6.79 billion to USD 3.1 billion if GERD operation is delayed from 2024 to 2030. The total loss to Ethiopia in terms of foregone real GDP gain is in the order of USD 24.7 billion if the GERD operation is delayed from 2024 to 2030. Sudan's economic loss is estimated at USD 1.96 billion and USD 4.47 billion, respectively, if GERD operation is extended by three and six years. Similarly, Egypt faces an economic cost that amounts to USD 297 million and USD 790 million if GERD operation is delayed by three and six years, respectively. Thus, the simulation results indicate that delaying the operation of the GERD has significant economic costs to all the Eastern Nile countries so that extending the filling (and hence operation) period of the dam defies economic rationality.

The findings of this study point to the following recommendations. First, although all Eastern Nile countries incur costs due to delays in GERD operation, Ethiopia's economic cost appears to be significant. Therefore, it is imperative that Ethiopia ensures timely completion of the dam to maximize the gains and minimize the costs. Second, given the mutual benefits of the GERD for the Eastern Nile countries, there is a strong economic rationale for basin – wide cooperation to finalize the dam without delays.

# 1. Introduction

The starting point of this study is the recognition that Ethiopia is endowed with abundant water resources and enormous hydropower potential. Its theoretical hydropower capacity (650 TWh/year) is second only to the Democratic Republic of Congo in Africa and its technically and economically viable potential are estimated at 260 TWh/year and 162 TWh/year, respectively (WEC, 2010). However, only a tiny fraction of this potential has so far been utilized. Though the country has recently raised its hydroelectricity generation capacity to 11 TWh, access to energy remains severely constrained with 56 percent of the population (60 million people) lacking access to electricity[6].

Ethiopia is endowed with a huge potential of renewable energy resources, including 45,000 MW of hydropower, 5.5 kW/$m^2$/day of solar power, 10,000 MW of geothermal power, and wind power estimated at 7 $m^2$/ second at 50 meter (Woldehanna, 2019).[7] Despite this potential and increased energy generation capacity, Ethiopia still has the second largest energy access deficit in Sub-Saharan Africa (after Nigeria), and the third in the world.[8] About 56 percent of Ethiopia's population still lacks access to electricity (MoWIE, 2020). The completion of the Grand Ethiopia Renaissance Dam (GERD) is expected to improve access to electricity for the vast majority of the population as well as stimulate the economy.

The energy constraint facing the country is exacerbated by increasing demand driven by increasing economic growth. Over the past decade, this was on average 10.7 percent per year (World Bank, 2013) and in the next decade (2020 – 2030) the economy is projected to rise, on the average, at the rate of 10.2 percent annually mainly driven by the expansion of the most energy – intensive manufacturing sector which is projected to grow by 20.6 percent annually

[6] MoWIE, Technical Facts and View Points on GERD – Issue 1
[7] Woldehanna, F. (2019). Energy Sector Overview: Reform Directions, Paper presented at Water and Energy Week, Ethiopian Skylight Hotel, Addis Ababa.
[8] https://www.worldbank.org/en/news/press-release/2018/03/01/world-bank-supports-ethiopias-endeavors-to-provide-all-citizens-with-access-to-electricity

during the period[9]. The country's demand for electricity is thus forecasted to increase more than six-fold in the next few years from 6.3 TWh/year in 2013 to 40.5 TWh/year in 2023 (Parsons Brinckerhoff, 2013). Sustaining economic growth and meeting the growing demand for electricity requires further development of the country's energy sector. The GERD constitutes the centerpiece of the country' plan to boost its hydroelectric generation capacity. The GERD, being built in the Blue Nile River close to the Ethiopian border with Sudan, has a design capacity of 6,000 MW and is reported to be able to produce 15.1 TWh/year upon completion (MDI, 2012). This would mean a massive additional energy source in the country and is expected to create enough supply to meet domestic as well as export demand for electricity.

The Blue Nile River over which the dam is being constructed constitutes the most important source of water supply to downstream countries Sudan and Egypt. The GERD project has therefore been a source of concern for these downstream countries. Ethiopia argues that the GERD will offer several benefits to downstream countries, including hydropower supply at a comparably cheaper price, flood control, water saving through reduced evaporation loss from the reservoirs of downstream dams and trapping silt. In order to create trust and consensus on sharing the dam's benefits, the Eastern Nile countries agreed on the establishment of an International Panel of Experts (IPoE), tasked with assessing the impact of the dam on downstream countries. The IPoE's report indicates, among other things, that the dam could potentially offer significant benefits to all the three Eastern Nile countries (MoFA, 2013). This corresponds with the findings of recent studies on the dam (Kahsay et al., 2015; Arjoon et al., 2014). Despite several rounds of negotiations and consultations held recently under the auspices of the United States, the World Bank and the African Union, Egypt and Sudan remain skeptical of the basin-wide economic significance of the dam. Further negotiations are imperative to resolve the disagreements of the Eastern Nile countries over the filling strategy of the GERD and avoid potential conflict between the countries. For future negotiations to succeed, the countries need to negotiate in good faith based on

[9] PDC, forthcoming 10-year perspective plan

scientific evidence on the potential economic impacts of the dam to which this study contributes.

In the literature, the economic impacts of dams have been assessed using partial and general equilibrium modeling approaches. Several studies analyzed the economic effects of infrastructure development in the Blue Nile River in Ethiopia using partial equilibrium models (e.g. Jeuland, 2010a; Jeuland, 2010b; Whittington et al., 2005; Block and Strzepek, 2010; Goor et al., 2010). However, Computable General Equilibrium (CGE) models are best-suited to analyze the direct as well as indirect impacts of dams (Robinsen et al., 2008). Computable General Equilibrium (CGE) models consider the entire economy as an interdependent system, therefore providing an economy-wide perspective. Unlike partial equilibrium models, CGE models account for various inter-linkages between economic sectors to analyze economy-wide effects that could occur as a consequence of policy interventions such as big dams.

This study employs a global CGE model to analyze the transboundary economic significance of the GERD operation and assesses the economic cost of delaying the operation of the dam (i.e. extending the filling period of the dam). More specifically, the study uses the revised version of the GTAP-W model (Calzadilla *et al.* 2010) to assess the potential transboundary economic significance of the GERD operation and estimates the economic cost of delaying the operation of the dam on the economy of the Eastern Nile countries: Ethiopia, Sudan and Egypt.

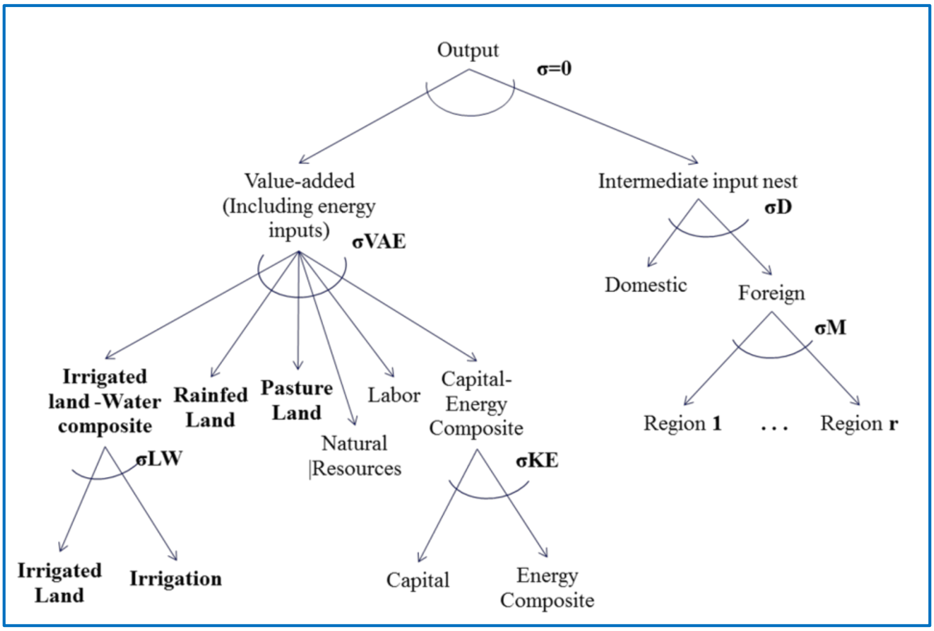
# 2. Modeling framework and data

## 2.1. Modeling framework

The modeling framework applied for the study is the Global Trade Analysis Project (GTAP) model (Hertel, 1997), developed at the Center for Global Trade Analysis, Purdue University, USA. GTAP provides a global modeling framework and a common global database that gives researchers the opportunity to conduct comparable model implementations and policy simulations. GTAP is a comparative static, multi-region, multi-sector computable general equilibrium (CGE) model of the world economy that examines all aspects of an economy via its general equilibrium feature. The standard GTAP model comprises accounting relationships, behavioral equations and global sectors required to complete the model. The accounting relationships of the model ensure the balance of receipts and expenditures for every agent identified in the economy, whereas the behavioral equations specify the behavior of optimizing agents in the economy (i.e. production and demand functions) based on microeconomic theory (Brockmeier, 2001).

This study uses the new version of the GTAP-W model (Calzadilla *et al*., 2010a). The new GTAP-W model is a refinement of the original GTAP-W model introduced by Berrittella *et al*. (2007). GTAP-W is a multi-regional world CGE model especially designed to account for water resources. In the original GTAP-W model, water is incorporated into the basic production structure of the model combined with the value-added nest (including energy inputs) and the intermediate inputs nest in fixed proportion via a Leontief function to produce final output (see Figure 2.1). The basic change in the new GTAP-W model is reflected in a new production structure that splits the land endowment in the value-added nest into rainfed land, irrigated land and irrigation water. Unlike the original GTAP-W model that incorporates water into the production structure as a non-substitutable factor of production, the revised GTAP-W model distinguishes between rainfed and irrigated agriculture and implements water as a factor of production directly substitutable in the production process of irrigated agriculture (see Figure 3.3).

**Figure 1: New GTAP-W Model: Truncated nested production structure**




Source: Calzadilla *et al*. (2010a).

## 2.2. Data and aggregation

The GTAP 9 Data Base is used for the study. The GTAP 9 Data Base includes 140 regions and sixty-eight commodities and features three reference years (2004, 2007 and 2011) (Aguiar 2016). More specifically, the study uses the GTAP-Power 9 Database, an electricity-detailed extension of the GTAP 9 Data Base, which disaggregates the electricity sector in the GTAP 9 Data Base into twelve sub-sectors (Peters 2016). The latest reference year of the database (2011) is used as a baseline for the study, and the 140 regions are aggregated into eight regions: Egypt, Ethiopia, Sudan (pre-2011), the Equatorial Lakes (EQL) region, Rest of East Africa, Rest of North Africa, Rest of Sub-Sahara Africa and Rest of the World (ROW) (Appendix 1). The four EQL countries covered in the GTAP 9 Data Base are Rwanda, Kenya, Tanzania and Uganda. In the GTAP 9 database, Sudan is aggregated in the Rest of Eastern Africa region. The SplitReg Program (Horridge 2011a) is employed to split off Sudan from the composite region based on the share of Sudan in the region's total value of endowments. The split database is verified using the GTAPAdjust Program (Horridge 2011b). The regional aggregation highlights the importance of the Eastern Nile region since the GERD directly affects the three Eastern Nile countries.

For the purpose of this study, the sixty-eight sectors in the GTAP-Power 9 Data Base will be aggregated into twenty sectors, of which eight are agricultural and twelve non-agricultural sectors (See Appendix 2). The electricity sub-sectors in the Data Base will be aggregated into three (hydropower, fossil and other sources). Following Calzadilla et al. (2011), the agricultural land endowment in the standard GTAP database will be disaggregated into rain-fed land, irrigable land and irrigation water, based on data generated by the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) model developed at the International Food Policy Research Institute (IFPRI) (Nelson et al. 2010). The IMPACT model provides detailed baseline data for the year 2000 and simulation to the year 2050 with respect to irrigation water use, crop yields and cropped area, distinguishing between 20 rainfed and irrigated crops and 281 food processing units for 115 economies and 126 river basins. The relative share of rain-fed and irrigated production in total production will be used to split the land rent in the original GTAP database into a value for rain-fed land and a value for irrigated land for each crop in each region. The five factors of production (endowments) in the standard GTAP model that include land, skilled labour, unskilled labour, capital and natural resources are thus disaggregated into eight endowments (irrigation water, irrigated land, rainfed land, pasture land, unskilled labour, skilled labour, capital and natural resources) in the GTAP – W model.

## 2.3. Macro projection

The base year of the GTAP 9 Database used for the study is 2011 so that the baseline is based on data for this year. A 9 – year macro-projection (2011-2018) that reflects the developments in terms of population growth, the size of labour and capital endowments and economic growth that have taken place inside and outside the Nile Basin since 2011 has been implemented to identify future baseline conditions and outcomes. In effect, the projection imposes a new macroeconomic equilibrium on the world economy including Ethiopia with higher levels of population, capital, labor, and GDP. Table 1 presents the cumulative growth rates used to construct the baseline with a projection of the world economies from 2011 onwards. Major macroeconomic data are updated and the effect of the GERD operation in the Eastern Nile Basin region is evaluated relative to this updated baseline situation. A two – year simulation (2019 and 2020) of sectoral growth in the Ethiopian economy has also been implemented to further update the baseline to 2020.

**Table 1: Cumulative growth rates (%) in population and factor endowments, 2011-2018**

| Region | Population | Capital* | Labor** | |
|---|---|---|---|---|
| | | | Unskilled | Skilled |
| Ethiopia | 20.9 | 26.6 | 26.6 | 224.5 |
| Sudan (pre-2011) | 14.7 | 18.9 | 18.9 | -27 |
| Egypt | 16.2 | 8.5 | 8.5 | 52.5 |
| EQL Region | 22.9 | 25.6 | 25.6 | 52.4 |
| Rest of East Africa | 15.3 | 24.1 | 24.1 | 191 |
| Rest of North Africa | 5.1 | 9.8 | 9.8 | 41.5 |
| Rest of Sub-Sahara Africa | 18.1 | 30.3 | 30.3 | 16.7 |
| Rest of the world | 8.4 | 7.6 | 7.6 | 26.8 |

Source: World Development Indicators, 2011 – 2018.

## 3. Scenario design

There are essentially two phases in the process of implementing the GERD project: GERD impounding and GERD operation. According to Tractebel Engineering GDF Suez and Coyne et Bellier (2011), GERD impounding is expected to be realized in 6 years if it occurs in a sequence of average or wet years. In case it occurs during a sequence of dry years, GERD impounding will require one more year and will be realized in 7 years. Nevertheless, assuming an annual GERD release of 31 to 33 $km^3$, recent MoWIE assessment reveals GERD filling would require 3 years, 4 to 5 years, 5 to 6 years and 10 years if it occurs during wet, average, dry and extreme dry hydrological conditions, respectively[10]. Assuming average hydrological conditions, 4 years (2020 – 2024) is considered to be feasibly ideal GERD filling period for this study. That is, GERD is expected to be operational in 2024.

Two scenarios are considered in assessing the economic and social significance of the GERD. First, economic effects of GERD operation on the Eastern Nile economies is assessed assuming it will be realized in 2024. Once operational, the GERD would not entail a significant reduction of water flowing to downstream countries. Since hydropower production is a non-consumptive water related activity, the flow of the Nile would not diminish significantly once the reservoir is filled. Whilst the evaporation loss is expected to increase in the GERD reservoir, estimated at about 1.7 $km^3$/year (MDI, 2012), evaporation losses from the HAD reservoir are expected to decrease once the GERD becomes operational. According to Blackmore and Whittington (2008), full development of the Ethiopian portion of the Blue Nile hydropower potential, i.e. the construction of four dams with a combined reservoir storage capacity equivalent to that of the GERD, would reduce the HAD evaporation losses by 1.9 $km^3$/year. With GERD operating upstream, Egypt would thus gain a 3.6 percent increase in irrigation water supply from system wide reduction in evaporation loss (Kahsay et al., 2015).

[10] Communications with members of the advisory team of the Ministry.

The GERD will boost Ethiopia's energy potential substantially. When fully operational, the GERD is expected to generate about 15.7 TWh energy per year.[11] This corresponds to an increase in the country's hydropower production by 142.7 percent. The construction of the GERD will also increase Ethiopia's capital stock by about 6.3 percent. Sudan is expected to benefit from the GERD operation in many respects. The GERD is expected to trap much of the silt from the Blue Nile river that would otherwise fill up Sudan's dams and will increase the existing power generated at Roseires, Sennar and Merowe hydropower plants by about 35.5 percent from 8.5 TWh/year to more than 11.6 TWh/year (Asegdew *et al*., 2014). This corresponds to an increase in hydropower production of 35.4 percent (Kahsay *et al*., 2015). The GERD is also expected to reduce the negative impacts on agriculture as well as economically valuable infrastructure in Sudan caused by recurrent floods. In addition to saving lives, it is expected that the GERD will help to prevent more than USD 200 million in annual flood risk damage along more than 1,000 km of the Blue Nile river from the Ethiopia-Sudan Border to Khartoum (MDI, 2012). Flood damage risk will also be avoided in cities like Dongola, located far north of Khartoum that experience recurrent and devastating floods (ENTRO, 2006). Reduced sedimentation due to the GERD operating upstream is expected to protect Sudan's irrigation canals and equipment from damages, avoid much of the reservoir and canal dredging costs, and increase the life span of Sudanese reservoirs. Overall, flood damage reduction, reduced sedimentation and hence the increased life span of dams induced by GERD operation are assumed to augment Sudan's capital stock by 3 percent (Kahsay *et al*., 2015) in the GERD operation stage.

The GERD will create a regulated flow in the Blue Nile River and the main Nile River, and will offer as a result a more stable flow over the whole year for irrigated agriculture and hydropower production in Sudan and Egypt. This would ensure a more continuous irrigation water supply (increased by 5 percent) and improved water use efficiency than is the case without the GERD, resulting in 5 percent improvement in irrigation efficiency in Egypt and Sudan (Kahsay *et al*., 2015). However, the GERD would reduce the High Aswan Dam (HAD)

[11] MoWIE, Technical Facts and View Points on GERD – Issue 1

power generation by 8 percent due to loss of head as the HAD would operate at a lower level with the GERD operating upstream (Asegdew *et al*., 2018; Kahsay *et al*., 2015).[12] But the overall net gain to Egypt would be positive. Table 2 provides the main assumptions underlying the scenario related to GERD operation.

**Table 2: Main assumptions underlying GERD operation (in % change)**

| | **Ethiopia** | **Sudan** | **Egypt** |
|---|---|---|---|
| Hydroelectricity production | +142.7 | +35 | -8 |
| Capital stock | +6.3 | +3 | 0 |
| Irrigation water supply | 0 | 0 | +3.6 |
| Water use efficiency | 0 | +5 | +5 |

Source: Asegdew *et al*. (2018); Kahsay *et al*. (2015)

In the second stage, the economic cost of delaying the GERD operation beyond 2024 is assessed. The issue of GERD filling period has been the single most important source of contention between Ethiopia and downstream countries, Sudan and Egypt. Egypt in particular has been adamantly opposed to the GERD filling in a reasonable period of time. In fact, Egypt has always been trying to coerce Ethiopia into extending the GERD filling period to unacceptably long period of time. This makes assessing the economic costs or benefits to Ethiopia and the downstream countries of extending GERD filling period beyond four years up to 10 years. That is, this involves examining basin-wide and country-specific economic repercussions of extending GERD filling and hence GERD operation between 2025 and 2030. Throughout the period, the Ethiopian economy is assumed to expand at the rate estimated in the forthcoming ten–year perspective development plan.

[12] According to MDI (2012), though more constant flows arrive at HAD all over the year with GERD operating upstream, the mean HAD water level is reduced to 167 meters which is 4 meters lower than the case without the GERD. This results in lower head and hence lower energy generation from HAD. This could be related to evaporation loss and seepage from the GERD reservoir.

# 4. Simulation results

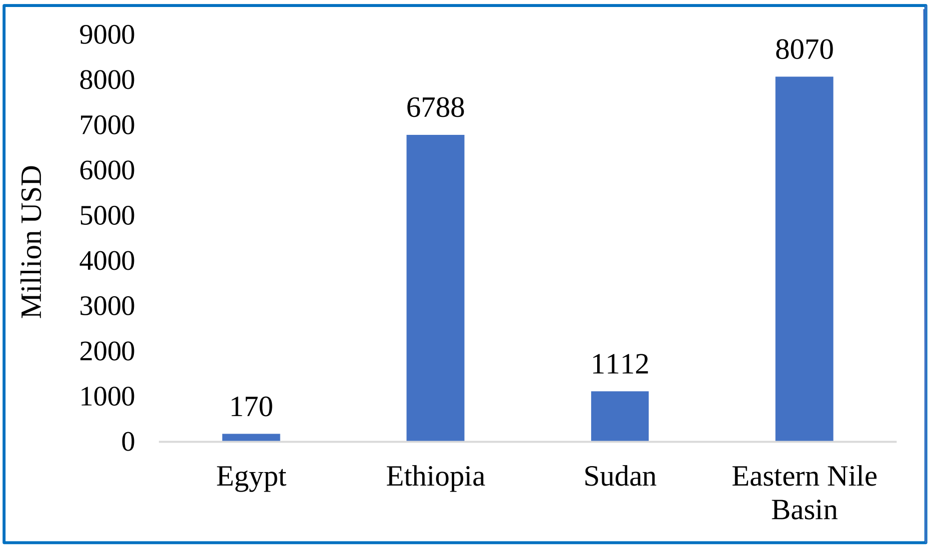
This section presents the results of the simulations to assess the direct and indirect economic effects of GERD operation in 2024 on the Eastern Nile economies and the economic consequences of delaying GERD operation beyond 2024. Changes in real GDP, economic growth, household income, and welfare effects relative to the baseline are used in measuring the economic effects of the operation of the dam and assessing the economic costs of delaying it.

## 4.1. Economic effects of GERD operation in 2024

The simulation results reveal that the GERD operation stimulates real GDP in the Eastern Nile basin (Figure 2). The basin-wide gain in real GDP due to GERD operation is in the order of USD 8.07 billion. Ethiopia earns a staggering USD 6.79 billon of the total basin-wide gain in real GDP induced by GERD operation while Sudan and Egypt earn USD 1.11 billion and USD 0.17 billion gain in real GDP, respectively. Thus, all the Eastern Nile countries are expected to benefit from GERD operation. Yet, the distribution of the benefits is highly skewed with Ethiopian amassing 84 percent of the GDP gain followed remotely by Sudan that gains 14 percent of the benefit. Egypt earns a mere 2 percent of the basin – wide gain in GDP. This reveals that the GERD involves no potential economic costs on both Egypt and Sudan. Thus, accounting for engineering estimates[13] of GERD's impact on HAD power generation, the net economy-wide effect is positive for all countries including Egypt, reflecting a win-win outcome. This underscores the fact that the benefits of the GERD should be seen in the wider basin –wide economic perspective.

[13] See, for instance, Asegdew *et al*. (2018).

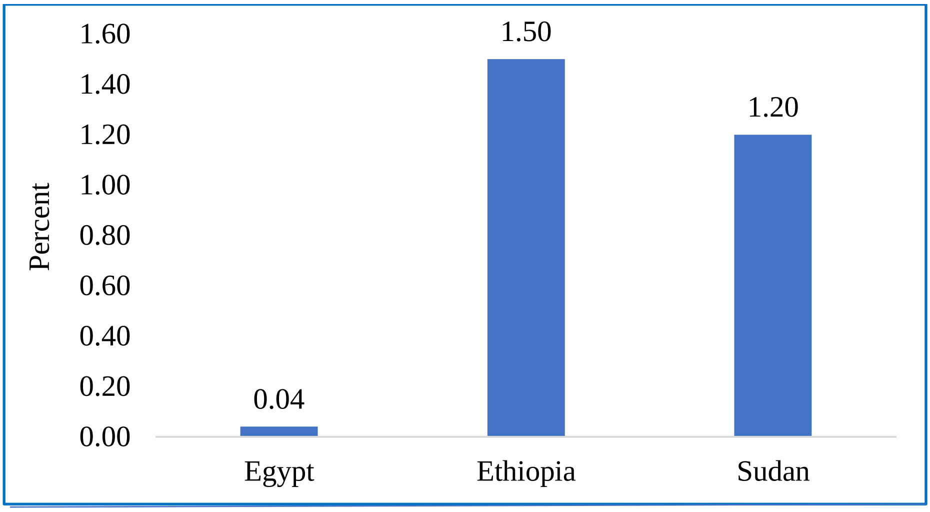
**Figure 2: The effect of GERD operation on real GDP**




Source: Simulation results

The Ethiopian economy is expected to grow at the rate of 1.5 percent due to GERD operation (Figure 3). GERD induced economic growth of Ethiopia is anchored mainly on the tremendous improvements in energy supply which in turn increases efficiency, capacity utilization and productivity for the energy–constrained economy. Some studies (e.g. Abdisa, 2018; Carlsson *et al*., 2018) indicate that power outage decreases productivity and increases cost of production of Ethiopian firms. Similarly, the economy of Sudan expands by 1.2 percent with GERD operating upstream, mainly due to enhanced capital stock resulting from the GERD induced flood damage reduction. Reduced sediment load and hence enhanced power generation in Sudan's power plants induced by GERD operation would also stimulate economic growth in the Sudan. With benefits in terms of improved water use efficiency, the GERD would further improve economic growth in the Sudan. GERD operation does offer significant benefits for Egypt's economy in terms of increased water supply due to reduced evaporation loss from the HAD, as well as the opportunity for improving water use efficiency as a result of a more regulated flow of water throughout the year. Overall, the results show that GERD operation would enhance Egypt's economy to a certain extent (0.04%).

**Figure 3: The effect of GERD operation on economic growth**




Source: Simulation results

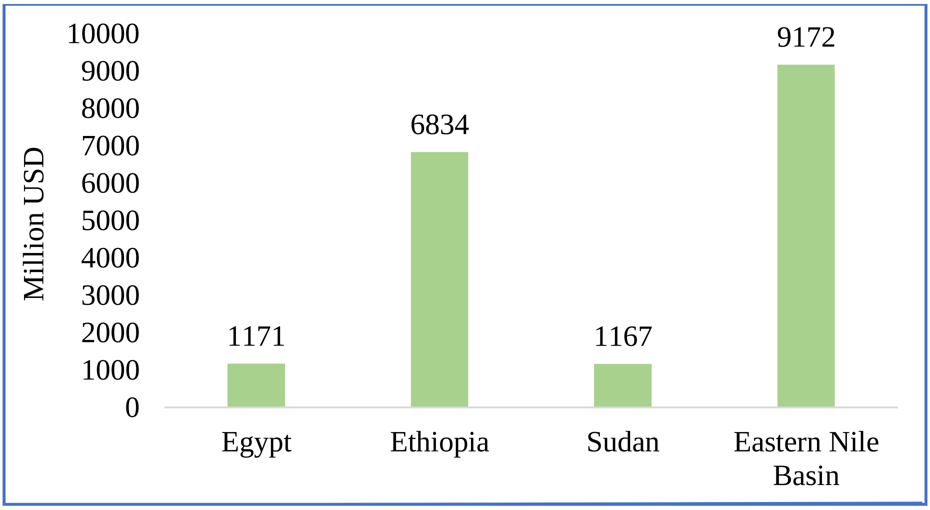
The welfare effects of the GERD, as measured by the equivalent variation (EV)[14], would be substantial. The total welfare gain in the Eastern Nile countries induced by GERD operation is about USD 9.17 billion. Ethiopia is expected to benefit a welfare gain of about USD 6.83 billion while the Sudan and Egypt are expected to experience a welfare gain of USD 1.17 billion each (Figure 4). Thus, all the Eastern Nile countries experience a positive welfare change due to GERD operation, although the distribution is uneven with Ethiopia, Sudan and Egypt earning 74, 13 and 13 percent of the total welfare gain, respectively.

The simulation results reveal that the GERD improves the real return to unskilled labor in the Eastern Nile countries. The real return for unskilled labor improves by 8.8, 0.9 and 0.5 percent in Ethiopia, Sudan, and Egypt, respectively due to GERD operation. The real return to unskilled labor measures the changes in return to unskilled labor relative to the price index of consumption expenditure and hence reflects trends in poverty reduction. Thus, the GERD is of significant importance in reducing poverty, mainly in Ethiopia and to some extent in Sudan and Egypt. Results for household income exhibit a similar

[14] Equivalent variation measures here the amount of income that would have to be given to an economy before building the dam so as to leave the economy as well off as it would be after the dam has been built.

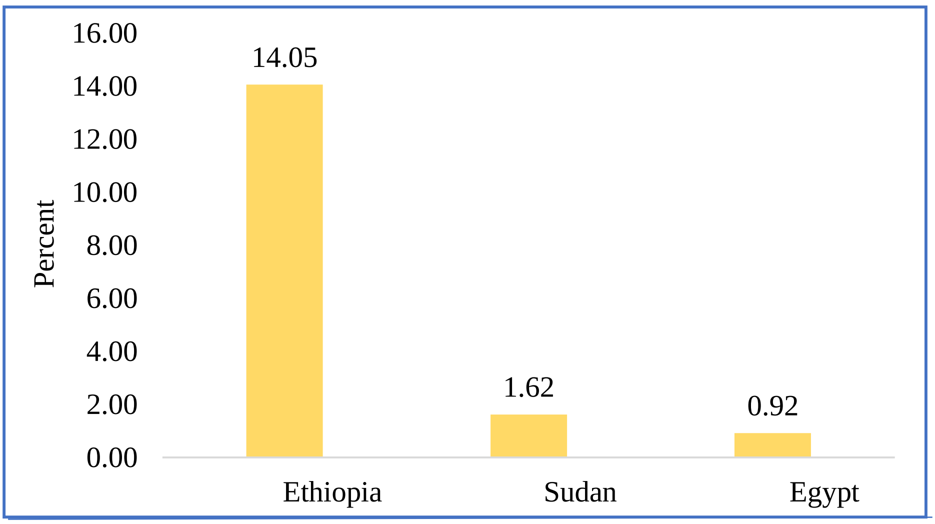
pattern (Figure 5). Ethiopia enjoys the largest improvement in household income from GERD operation due to increased economic activity and productivity. The GERD operation would also improve household income in Sudan and Egypt. Improved household income induced by the GERD operation is expected to contribute to improving household consumption and hence improve the standard of living of the Eastern Nile population.

**Figure 4: The results of GERD operation on Welfare**




Source: Simulation results

**Figure 5: The results of GERD operation on household income**

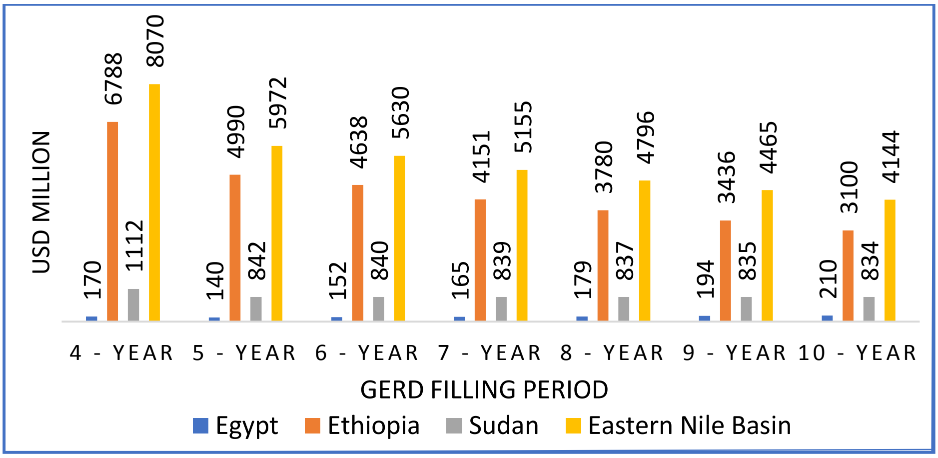



Source: Simulation results

## 4.2. Economic consequences of delaying GERD operation

The effect of the GERD on real GDP in the Eastern Nile economies varies for different filling period of the dam. The gain in real GDP of the Eastern Nile basin declines to USD 5.97 billion when GERD operation is delayed by a year (i.e. it becomes operational in 2025). Extending GERD filling period by three and six years would bring its basin – wide economic significance (in terms of contribution to real GDP) down to USD 5.15 billion and USD 4.15 billion, respectively, from USD 8.07 billion gain in basin – wide real GDP expected to be realized if the GERD is filled in four years (2020 – 2024) period (Figure 6). Apparently, basin–wide gains in real GDP would dwindle successively as GERD operation phase is extended beyond 2024. The declining basin–wide real GDP gain is influenced mainly by the adverse effect of delayed operation of the dam on the real GDP gain of Ethiopia and to a lesser extent on that of the Sudan. Ethiopia's real GDP gain from the GERD is estimated to decline successively from USD 6.79 billion to USD 3.1 billion if GERD operation is delayed from 2024 to 2030 (i.e. delays by six years)[15] . The total loss to Ethiopia in terms of foregone real GDP gains due to delays in GERD operation up to 2030 would be USD 24.68 billion. Sudan and Egypt would lose a total real GDP gain of USD 4.47 billion and USD 790 million, respectively, for the same reason.

**Figure 6: Effect of extending GERD filling period on real GDP**

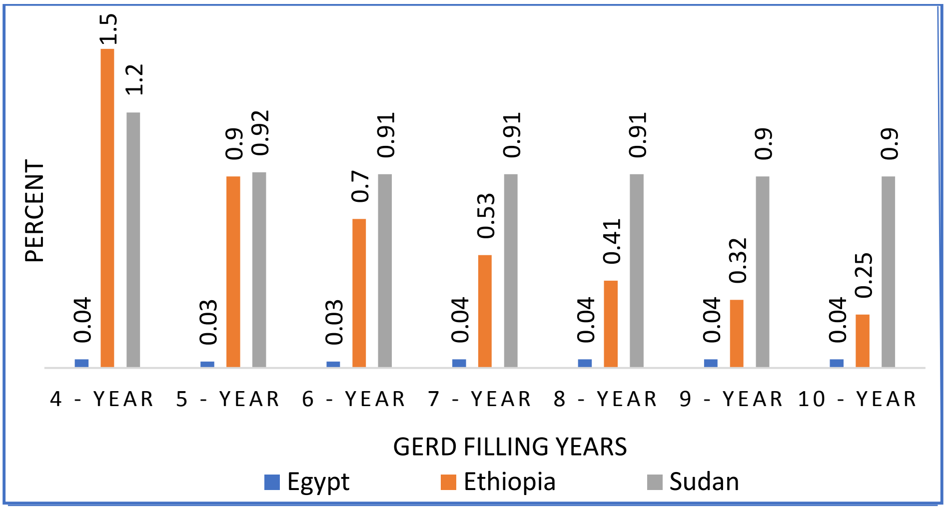



[15] If the GERD is filled and hence becomes operational in the 6th year, then there is a delay of two years as it is supposed to generate energy in the 4th year (i.e. 2024). Similarly, if the GERD has become operational in the 10th year, there will be a delay of six years.

Source: Simulation results

Delaying the GERD operation period would also diminish economic growth in the Eastern Nile countries (Figure 7). Extending GERD operation by six years to 2030 diminishes GERD induced economic growth in Ethiopia and Sudan to 0.25 and 0.9 percent, respectively, as compared to 1.5 and 1.2 percent economic growth the countries could achieve if the GERD goes operational in 2024. Economic growth rate in Egypt would also oscillate between 0.04 and 0.03 percent and remains, on the average, stable at 0.04 percent for all GERD operation periods considered.

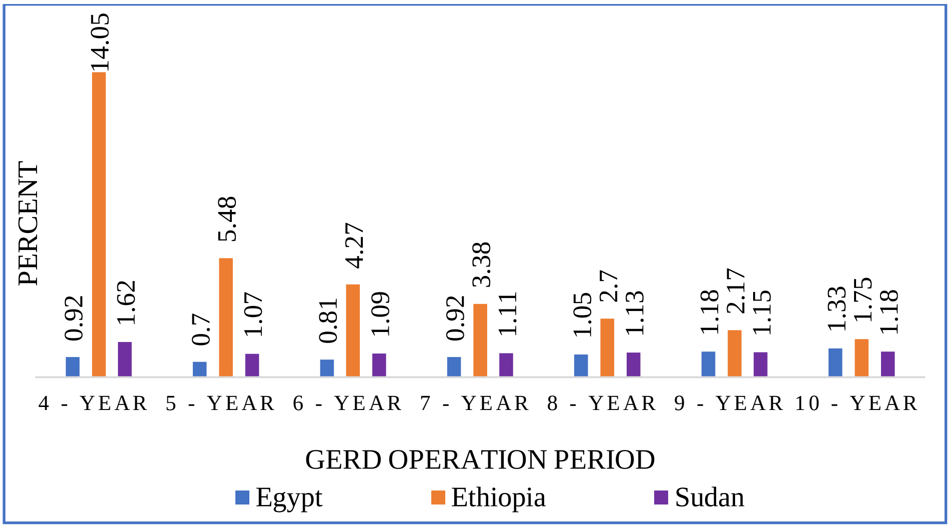
**Figure 7: Effect of extending GERD filling period on economic growth**




Source: Simulation results

Gains in household income is expected to decrease for all countries as GERD operation period is extended beyond the assumed period (i.e. 2024) (Figure 8). If the GERD operation is delayed by three and six years, Ethiopia would experience a decline in household income to 3.38 percent and 1.75 percent, respectively. For Sudan, gains in household income declines from 1.62 percent to 1.18 percent when GERD operation is delayed by six years (i.e. if GERD becomes operation in the year 2030 instead of 2024). Growth rate in household income in Egypt would increase from 0.92 percent to 1.33 percent over the same period.

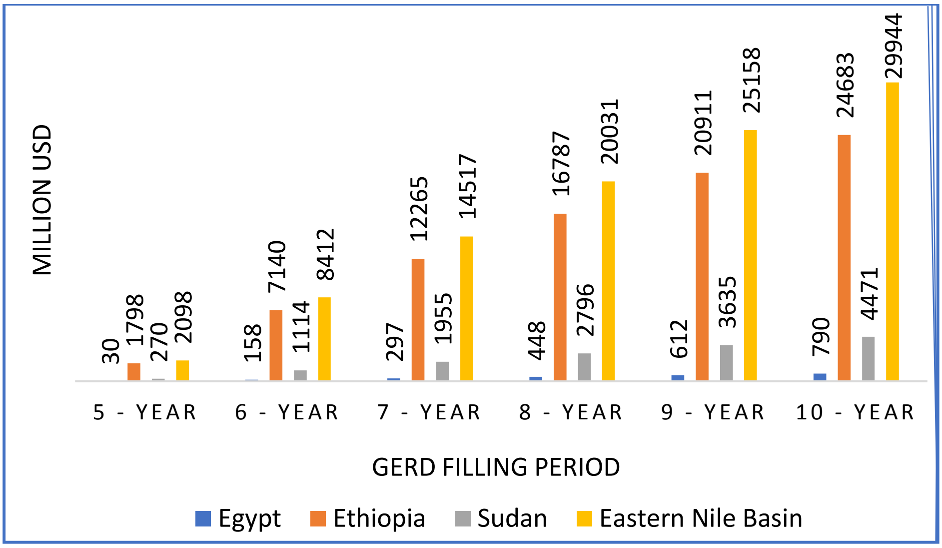
**Figure 8: Effect of extending GERD filling period on household income**




Source: Simulation results

The effect of the GERD in enhancing real GDP is substantial but decreases as the GERD operation period delays. The economic cost of postponing GERD operation by extending the filling period of the dam is quite significant (Figure 9). Relative to GERD filling in four years, the total economic cost to the Eastern Nile basin countries of extending the GERD filling by a single year from four to five years, as measured by foregone gain in real GDP, is estimated at USD 2.1 billion. The economic cost is expected to increase to USD 8.4 and USD 14.5 billion if GERD operation is delayed by two and three years, respectively. Delaying the operation of the GERD by five and six years would entail a staggering economic cost of USD 25.2 billion and USD 29.9 billion, respectively, to the Eastern Nile economy. Delaying GERD operation involves a significant economic cost to all the Eastern Nile countries, albeit Ethiopia is disproportionately affected. Extending GERD impounding from four to five years would result in a net economic cost of USD 1.8 billion on the Ethiopian economy. Ethiopia's economic cost is expected to increase sharply to USD 12.3 billion and USD 24.7 billion, respectively, if GERD impounding is delayed by three and six years. If the operation of the GERD is delayed by a year, Sudan is expected to incur an economic cost of USD 270 million. Sudan's economic cost rises to USD 1.96 billion and USD 4.47 billion, respectively, if GERD operation is extended by three and six years. Similarly, Egypt would face an economic cost that increases from USD 30 million to USD 297 million and USD 790 million, respectively, when GERD operation is delayed by one, three and six years.

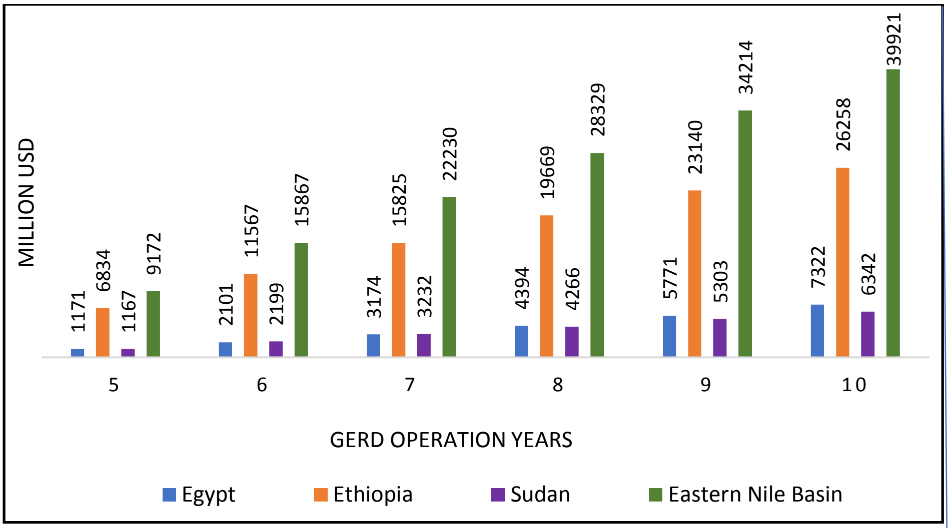
**Figure 9: Loss in real GDP associated to delaying GERD filling period**




Source: Simulation results

The simulation results for welfare loss due to extended GERD impounding and hence operation exhibit similar and yet more profound effect (Figure 10). Delaying the GERD operation period by one year entails a total welfare loss of USD 9.2 billion to the Eastern Nile basin economies. The total welfare loss rises to USD 22.2 billon and USD 28.3 billion, respectively, if GERD operation is delayed by three and four years. Extending GERD filling by six years results in a staggering USD 39.9 billion welfare loss in the Eastern Nile basin. Ethiopia shoulders much of the burden with 15.8 USD and 26.3 USD billion welfare loss associated with extending the GERD operation by three and six years, respectively. Egypt incurs a welfare loss of USD 3.23 billion and USD 7.32 billion due to the extension of GERD filling by three and six years, respectively. Similarly, Sudan experiences a welfare loss of USD 3.23 billion and USD 6.34 billion if the GERD operation is delayed by three and six years, respectively.

**Figure 10: Welfare loss associated to delaying GERD filling period**




Source: Simulation results

# 5. Conclusions and recommendations

Ethiopia is building a large hydropower dam known as the Grand Ethiopian Renaissance Dam (GERD) on the Blue Nile River close to the border with Sudan. The project has been a source of concern for downstream countries Sudan and Egypt. Employing a multi-region, multi-sector computable general equilibrium framework, this study estimates the economic effects of the GERD on the Eastern Nile economies. The study evaluates the significance of the dam in two steps. First, economic significance of GERD operation to the Eastern Nile economies assuming the dam will be filled in four years. In the second step, the economic cost of delaying GERD filling and hence operation beyond four years (5 to 10 years) is estimated.

The results of the analysis demonstrate the significance of the GERD in generating basin-wide economic benefits. GERD operation following four years impounding phase significantly enhances economic growth, household income and welfare in all the Eastern Nile countries. The GERD would also contribute to poverty alleviation in the Eastern Nile Basin by increasing real income to unskilled labour.

The results of the study corroborate the findings of previous studies (Strzepek, et al., 2008; and Aydin, 2010). This includes the findings of several hydrological models developed to evaluate the downstream impacts of Ethiopia's development of the Blue Nile waters to maximize hydropower production (e.g. Guariso and Whittington, 1987; Whittington et al., 2005; and Blackmore and Whittington, 2008). The results of the study are also consistent to the findings of recent studies on the economic effects of the dam (e.g. Kahsay *et al*., 2015; Kahsay et al., 2019; Arjoon *et al*., 2014). The findings of the present study, like that of previous studies, reveal that hydropower dams enhance economic growth.

Extending the filling phase of the dam beyond four years entails huge economic cost to the Eastern Nile economies in terms of foregone gains in real GDP and welfare. The economic cost rises rapidly as the impounding phase extends from five to ten years. Delaying the operation of the dam entails substantial economic cost to all the Eastern Nile economies though Ethiopia is heavily affected compared to the downstream countries, Sudan and Egypt. Thus, extending the GERD filling period and hence operation adversely affects the economy of the entire Eastern Nile basin so that no economic rationale can justify it.

Although all Eastern Nile countries incur costs due to delays in GERD operation, Ethiopia's economic cost appears to be significant. Therefore, it is imperative that Ethiopia ensures timely completion of the dam. Second, given the mutual benefit of GERD for Eastern Nile countries, there is a strong economic rationale for basin–wide cooperation to finalize the dam without delays.

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# Appendix

## Appendix 1: Regional Aggregation

| Region | Description |
|---|---|
| Egypt | Egypt |
| Ethiopia | Ethiopia |
| Sudan (pre-2011) | Sudan |
| Equatorial Lakes Region | Rwanda, Uganda, Kenya, United Republic of Tanzania |
| Rest of East Africa | Burundi, Comoros, Djibouti, Eritrea, Mayotte, Seychelles, Somalia |
| Rest of North Africa | Morocco, Tunisia, Algeria, Libyan Arab Jamahiriya, Western Sahara |
| Rest of Sub-Sahara Africa) | Benin, Burkina Faso, Cameroon, Cote d'Ivoire, Ghana, Guinea, Nigeria, Senegal, Togo, Cape Verde, Gambia, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Saint Helena, ASCENSION AND TRISTAN DA CUNHA, Sierra Leone, Central African Republic, Chad, Congo, Equatorial Guinea, Gabon, Sao Tome and Principe, Angola, Democratic Republic of Congo, Madagascar, Malawi, Mauritius, Mozambique, Zambia, Zimbabwe, Botswana, Namibia, South Africa, Lesotho, Swaziland |
| Rest of the World | New Zealand, Rest of Oceania, China, Hong Kong, Japan, Republic of Korea, Mongolia, Taiwan, Rest of East Asia, Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Philippines, Singapore, Thailand, Viet Nam, Rest of Southeast Asia, Bangladesh, India, Nepal, Pakistan, Sri Lanka, Rest of South Asia, Canada, united States of America, Mexico, Rest of North America, Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela, Rest of South America, Costa Rica, Guatemala, Honduras, Nicaragua, Panama, El Salvador, Rest of Central America, Dominican Republic, Jamaica, Puerto Rico, Trinidad and Tobago, |

| Region | Description |
|---|---|
| | Caribbean, Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, United Kingdom, Switzerland, Norway, Rest of EFTA, Albania, Bulgaria, Belarus, Croatia, Romania, Russian Federation, Ukraine, Rest of Eastern Europe, Rest of Europe, Kazakhstan, Kyrgyzstan, Rest of Former Soviet Union, Armenia, Azerbaijan, Georgia, Bahrain, Islamic Republic of Iran, Israel Jordan, Kuwait, Oman, Qatar, Saudi Arabia, Turkey, United Arab Emirates, Rest of Western Asia, Antarctica, Bouvet Island, British Indian Ocean Territory, French Southern Territories. |

EFTA: European Free Trade Association
WAEMU: *West African Economic and Monetary Union*
ECOWAS: Economic Community of West African States
CAEMC: Central African Economic and Monetary Community
SADC: South African Development Community
COMESA: Common Market for Eastern and Southern Africa
CU: Customs Union

## Appendix 2: Sectoral Aggregation

| Sector | Detail Description |
|---|---|
| **I. Agricultural Sectors** | |
| Paddy | Paddy rice |
| Wheat | Wheat |
| Cereals | Cereal grains not elsewhere classified (nec) |
| Other crops | Plant-based fibers; crops nec; processed rice |
| Vegetables and fruits | Vegetables, fruit, nuts |
| Oil seeds | Oil seeds |
| Sugar crops | Sugar cane, sugar beet |
| Livestock and meat | Cattle, sheep, goats, horses; animal products nec; raw milk; wool, silk-worm, cocoons; meat: cattle, sheep, goats, horses; meat products nec |
| **II. Non-agricultural sectors** | |
| Processed food | Vegetable oils and fats; dairy products; sugar; food products nec; beverages and tobacco products |
| Extraction | Forestry; fishing; minerals nec |
| Coal | Coal |
| Crude | Oil |
| Gas | Gas; gas manufacturing, distribution |
| Petroleum | Petroleum, coal products |
| Manufactures | Textiles; wearing apparel; leather products; wood products; paper products, publishing; chemical, rubber, plastic prods; mineral products nec; ferrous metals; metals nec; metal products; motor vehicles and parts; transport equipment nec; electronic equipment; machinery and equipment nec; |

| Sector | Detail Description |
|---|---|
| | manufactures nec |
| Water services | Collection, purification and distribution of water |
| Services | Construction; trade; transport nec; sea transport; air transport; communication; financial services nec; insurance; business services nec; recreation and other services; public administration, defense, health, education; dwellings |
| Electricity_hydro | Hydroelectric power as base load, Hydroelectric as peak load |
| Electricity_fossil | Coal-fired power, Gas-fired power as base load, Oil-fired power as base load, Gas-fired as peak load, Oil-fired as peak load |
| Electricity_other | Nuclear power; Wind power; solar power: photovoltaics and thermal; other power nec: waste, biofuels, biomass, geothermal, tidal; Transmission and distribution |

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