Implications of the initial filling of the Grand Ethiopian Renaissance Dam for the Egyptian Economy

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Background and Motivation

Negotiations over the initial filling of the Grand Ethiopian Renaissance Dam (GERD) are still ongoing between Egypt, Ethiopia, and Sudan. The GERD – a multi-year storage dam on the Blue Nile in Ethiopia – is expected to make Ethiopia Africa's biggest electricity exporter. The GERD will affect downstream water users in Egypt and Sudan. Several studies assessed the effects of the GERD on water supply and hydropower generation in Egypt and Sudan. However, less attention was given to the economic costs and benefits of GERD. Based on several media reports, a 40 BCM annual water release volume has been requested by Egypt, whereas Ethiopia is willing to release up to 30 BCM annually. We analyze the impacts of the two scenarios on the Egyptian economy.

Models and Data

In this study, we combine a monthly water allocation model with an economy-wide recursive dynamic computable general equilibrium (DCGE) model to assess the implications of the initial filling of the GERD for the Egyptian economy.

The monthly water allocation model covers the Eastern Nile Basin [1] and was used to quantify the impacts of GERD filling scenarios on water supply and hydropower generation in Egypt. This model includes 162 inflow nodes, 9 storage dams, 10 demand nodes, evaporation losses from the storage dams, and transmission losses from river reaches. The model was calibrated over a 103 year-period from 1900 to 2002. The model is driven by hydrological inflows and system operating rules. The model was built using RiverWare, a generalized water resources simulation software developed by the University of Colorado Boulder [2]. The model was used to examine two negotiated filling approaches for the Grand Ethiopian Renaissance Dam. Both approaches are based on fixed annual release volumes that are distributed evenly throughout the days of the year. Two fixed annual release volumes are examined to represent the negotiating positions of Ethiopia and Egypt: 30 and 40 BCM, respectively. Each of the two filling scenarios is examined across 103 stochastic hydrologic scenarios that are developed using the index sequential method [3,4]. The index sequential method applies the historical river flow record to the future by taking all years in the record as possible starting points. We assume that water supply shortages are distributed proportionally between the different water consumers in Egypt, including crop types. Recent radar altimetry data of the High Aswan Dam acquired from the Copernicus Global Land Operations [5] show that the reservoir was at 180.66 meters above sea level (m asl) on January 1, 2020. Therefore, we adopted an initial reservoir water level for the High Aswan Dam of 175 m asl, assuming that the reservoir water level would not drop below that by the start of the filling of the Grand Ethiopian Renaissance Dam.

We feed the outputs of the water allocation model on water supply and hydropower generation into a DCGE model of Egypt. The DCGE model is recursive-dynamic, covers the period from 2015 to 2050, and includes four agent types: households (105 groups), enterprises (7 groups), the government, and the rest of the world. Households and enterprises receive payments from producers in exchange for factors of production they own, pay direct taxes, and save based on saving propensities. Enterprises pay their income to households in the form of dividends. Households use their income to purchase commodities according to Linear Expenditure System (LES) functions. The government receives revenue from production taxes, sales taxes, direct taxes, and import tariffs. The government spends its income on transfers to households, enterprises, and the rest of the world. The government purchases commodities and saves the remaining income (with budget deficits representing negative savings). All savings of households, enterprises, the government, and the rest of the world (foreign savings) are collected in a savings pool from which investment is financed.

We calibrate the DCGE model to an extended version of the most recent social accounting matrix (SAM) of Egypt[6]. Given the importance of agriculture for income generation and satisfaction of consumer needs, the SAM disaggregates the agriculture sector by regions (7 regions) and activity types (20 agricultural activities); linkages between crop production and other sectors such as food processing, manufacturing, and services are specified in the SAM. The SAM includes 62 activities each produced in up to seven different regions, making a total of 395 activities. Among these production activities, 126 represent cropping, livestock herding, forestry and fishery. Agriculture contributes about 11.5% of Egypt's gross domestic product (GDP) and more than 25% of employment [7]. Moreover, the agriculture sector provides production inputs to agro-industry, uses various services in the economy (e.g., transportation), and competes with other sectors on electricity, capital, and water. The SAM of Egypt used herein classifies households by location to rural and urban groups. Rural groups are further classified by nature of activities into farming and non-farming groups. Each group is classified by income level to five quintiles and each quintile is disaggregated according to the regions to which they belongs (7 regions) leading to 70 rural household groups. Urban groups are classified according to income and regions (a total of 35).

The model includes 28 labor categories, disaggregated by education level (uneducated, primary-educated, secondary-educated and tertiary-educated) and regional affiliation (to seven regions). All labor types are assumed to be fully employed and mobile across sectors. The assumption of full employment is consistent with widespread evidence that, while relatively few people have formal sector jobs, most working-age people engage in activities that contribute to GDP.

Capital has 28 categories each classified according to use (i.e., cropping, livestock herding, mining, and others uses) and region of use (7 regions). Capital accumulation is modelled assuming a "putty-clay" formulation whereby new investments are allocated across sectors according to the rate of return differentials, but once installed, capital remains immobile within periods [8]. Cultivable land, which is differentiated by regions, is assumed fully employed, but activity-specific.

To capture the GERD impact on the Egyptian economy, we extended the Egyptian SAM to include four activities in relation electricity generation: two activities produce electricity commodities, namely, hydropower and non-hydropower generation; two activities for electricity distribution and transportation. In addition, we included to water-related activities, namely, irrigation and other water production.

The Egyptian economy is represented as a competitive economy with flexible prices such that consumers maximize their utility, and producers maximize their profits. The economy is connected with the rest of the world via trade, remittances, and other transfers. Producers are assumed to be price takers in output and input markets and maximize their profits using constant returns to scale technologies. Demands for production factors are determined using constant elasticity of substitution functions, whereas intermediate input demands are calculated using a Leontief function. Production for domestic and foreign markets is governed by constant elasticity of transformation functions that distinguish between exported and domestically consumed commodities. This approach captures quality differences between exported and domestically consumed commodities. Based on the smallcountry assumption, Egypt was assumed to have perfectly elastic import demand and export supply curves at fixed world prices. Imported and domestically produced commodities are treated as imperfect substitutes in both final and intermediate demands under constant elasticity of substitution Armington specification. Households use part of their income to consume commodities according to fixed budget shares.

The model includes three macroeconomic accounts: a government balance, a current account balance, and a savings-investment account. Macro-closure rules are specified to balance the three macro accounts taking into consideration how the Sudanese economy functions. In the government account, public savings are endogenous. Government demand for commodities is fixed, and all tax rates are held constant so that government savings or deficits depend on the level of economic activity. An investment-driven closure rule is assumed such that the share of investment in total absorption is fixed, while household saving rates adjust to generate the necessary funds. External capital inflows are fixed, while flexibility is provided to the exchange rate.

Simulations and Expected Outcome

The study investigates the economy-wide impacts of GERD filling on the Egyptian economy under two GERD filling scenarios and across 103 hydrologic scenarios. This makes 206 scenarios. The scenarios are examined in 30-year periods starting from 2020. Results are reported and analyzed considering different economy-wide, sectoral, and institutional indicators, including household group-specific welfare effects. The study is expected to improve the current state of understanding of the potential economic impacts of GERD filling on the Egyptian economy.

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