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Does Electricity Supply Strategy Matter? Shortage and Investment: Reflections based on CGE Analysis

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Abstract

Ethiopia's fast growing economy has brought about an unprecedented rise in power demand. Unfortunately, the demand could not be met in the last three years because of delays in capacity expansion and shortage of rainfall which resulted in power shortage. The government followed a rationing strategy to solve the problem in the short run while for the long run it has been investing heavily in power generation capacity with further intention to export. Using a Static CGE model, this study analyzed the impact of the electricity shortage on the economy. The analysis is based on IFPRI's standard CGE model and the 2005/06 Ethiopian Social Accounting Matrix (SAM). The paper assesses government's measure of electricity rationing (rationing that favors export sectors and disfavors selected sectors) and compares it with other alternative strategies (uniform rationing, rationing that favors export sectors, and rationing that favors activities of high electricity productivity). The study found that the impact of the shortage was significant, with a GDP loss of 3.1 percent. While the government's measure in favoring export oriented activities had a positive impact on GDP, the disproportionate disfavoring of other activities had a negative effect that outweighed the positive impact. Other rationing mechanisms could have a lower cost to the economy. The study also found that the government's plan in electricity investment and export would have a significant growth contribution to the economy. The investment is expected to bring about a 6.1 percent rise in GDP. The output growth is expected to come from the electricity generation and its effects as a vital input in the economy. However, the foreign exchange inflow from electricity export would bring an output reduction in other tradables as a result of the induced real exchange rate appreciation.

1. Introduction

Ethiopia's economy has been growing at a staggering average Gross Domestic Product (GDP) growth rate of 8.6 percent for the past 10 years (MOFED 2010); all the major sectors of the economy have shown a remarkable leap forward. The industry and service sectors have grown by 9.1 and 10.7 percent respectively on average over the period. The share of these sectors in the GDP is also increasing. In line with this, power consumption in the country, especially in the industry sector, has been increasing. Household electrification programs, mostly rural, have also contributed to the rise in power consumption.

However, the country's power supply hasn't kept pace with demand, both due to technical problems and delayed capacity expansions. Furthermore, as almost all of Ethiopia's electric power supply is from hydropower, shortage of rainfall adds to the problem. Consequently, the country endured a power shortage which has been worsening year after year over the past three years, 2007/08–2009/10[1].

To manage the problem, the government has been taking short and long term measures. As an immediate remedy, the Ethiopian Electric Power Corporation (EEPCo) went for rationing. Rolling blackouts had to be scheduled once or twice a week throughout the country and sometimes every other day depending on the shortage intensity. Almost all industries that use electric driven machineries lost power in shifts. Some industries like cement, steel manufacturing, and crushers at times lost power completely as the shortage got more serious in early 2009/10. Therefore, the power shortage created a situation that strained production processes of different activities, especially in urban centers. As a result, the speed of the economic growth slowed down.

Power shortage and its implication on an economy are not specific to Ethiopia. Studies on other developing countries show strong adverse effects of power shortage on the countries' economy. According to a study by Ferguson, Wilkinson, and Hill (2000), there is a strong correlation between electricity use and economic growth. The Pearson correlation coefficient between growth in annual electricity use and average annual economic growth for Sri Lanka during the period 1971–1995 is 0.993. Since energy demand in Sri Lanka is mainly met by hydropower, serious droughts have led to a dramatic decline in its economic growth. Additionally, a CGE analysis on the economy wide impact of electricity shortage on the South African economy, by Davies (2008), shows that electricity shortage has a very significant negative effect on the GDP. According to the study, a rationing measure as opposed to a market solution (price adjustment) for the problem caused GDP to fall by 10.1 percent.

The general objective of this paper is to understand the implications of electricity shortage and increasing electricity generation capacity on the Ethiopian economy. The specific objectives are: to critically evaluate the government's strategy to apply rationing as a short-term solution by comparing it with alternative rationing strategies; and to demonstrate the economic advantages of increasing electricity generation capacity in the long run, even beyond local needs and thus to be able to export electricity.

[1] The Ethiopian fiscal year begins in July and ends in June.

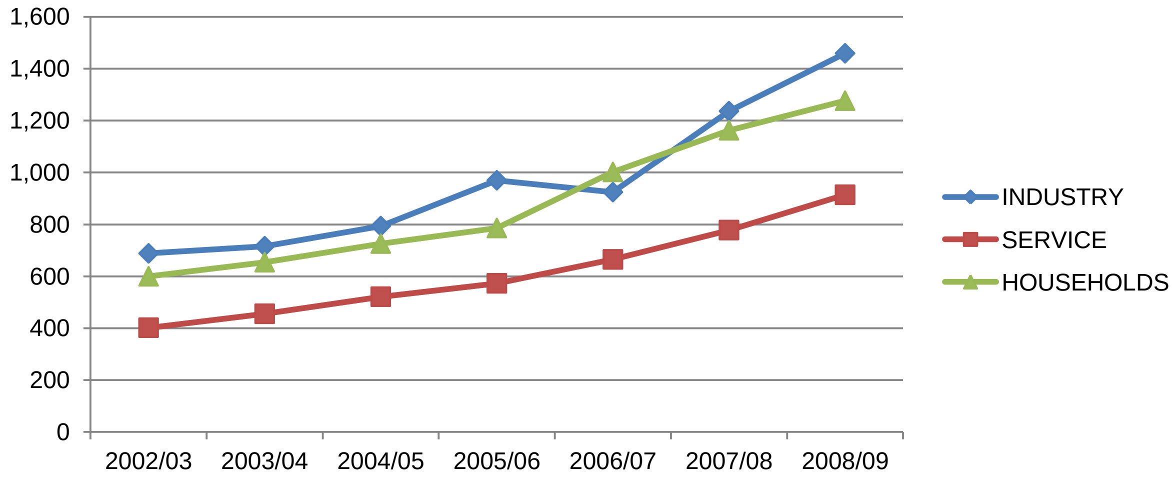
2. Electricity consumption and supply in Ethiopia

Ethiopia has an economically exploitable electricity generation potential of more than 45,000 MW from hydro, 5,000 MW from geothermal and 10,000 MW from wind (EEPCo) though only a fraction of this potential has been harnessed so far. The vast majority of its domestic energy need is still fulfilled by wood fuel and animal dung. During 2009/10, only about 41 percent of the population had access to electric energy (MOFED 2010) and even those who had the access couldn't get full service because the country was plagued by power outages.

2.1. Trend in electricity consumption

The Ethiopian economy has grown rapidly in recent years accompanied by increasing power consumption. According to data from EEPCo, power consumption has been increasing for all types of users (Figure 2.1). For the period 2002/03–2008/09, industries have been, on average, the number one users of electricity in Ethiopia followed by households. Increased power consumption by households is mainly due to the augmented use of electronic household utensils and due to the rural electrification program of the government.

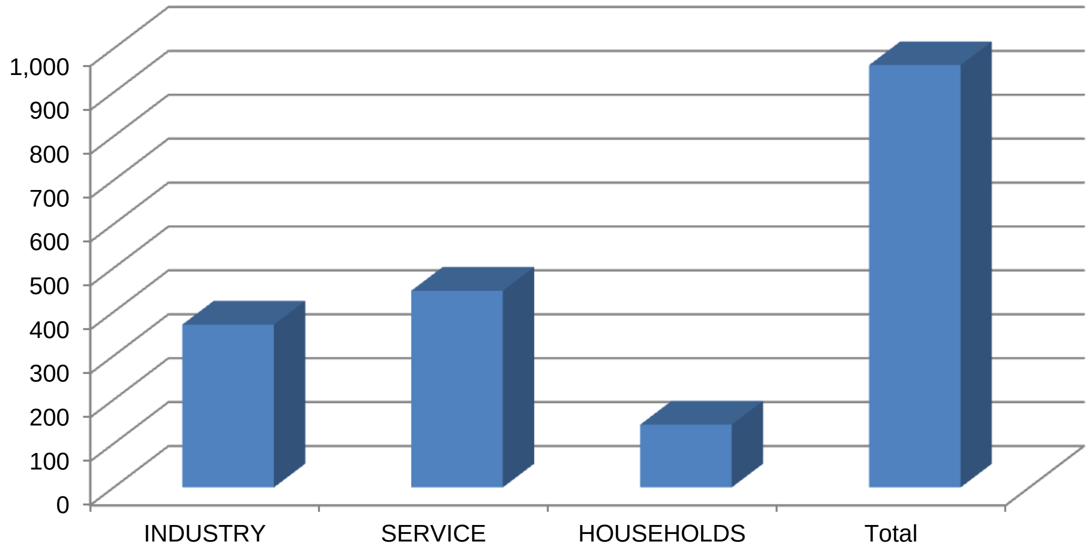
Figure 2.1. Power consumption trend by all users in Ethiopia (Gigawatt Hour (GWH))



Source: Based on data from EEPCo

In the usual trend, EEPCo expected power consumption to increase in 2009/10 fiscal year for all types of users (Figure 2.2). The largest rise as compared to the previous year was expected from the service sector which was rated as high as 448 GWH. Power consumption of the industry sector and households was expected to rise by 371 GWH and 143 GWH respectively. This constitutes to an expected rise in total power consumption of about 962 GWH in 2009/10, resulting to an expected total power consumption of about 4,546 GWH in 2009/10.

Figure 2.2. Expected rise in power consumption (GWH) by type of user in 2009/10 compared to 2008/09.



Source: Based on data from EEPCo

2.2. Electricity generation capacity: supply and shortage

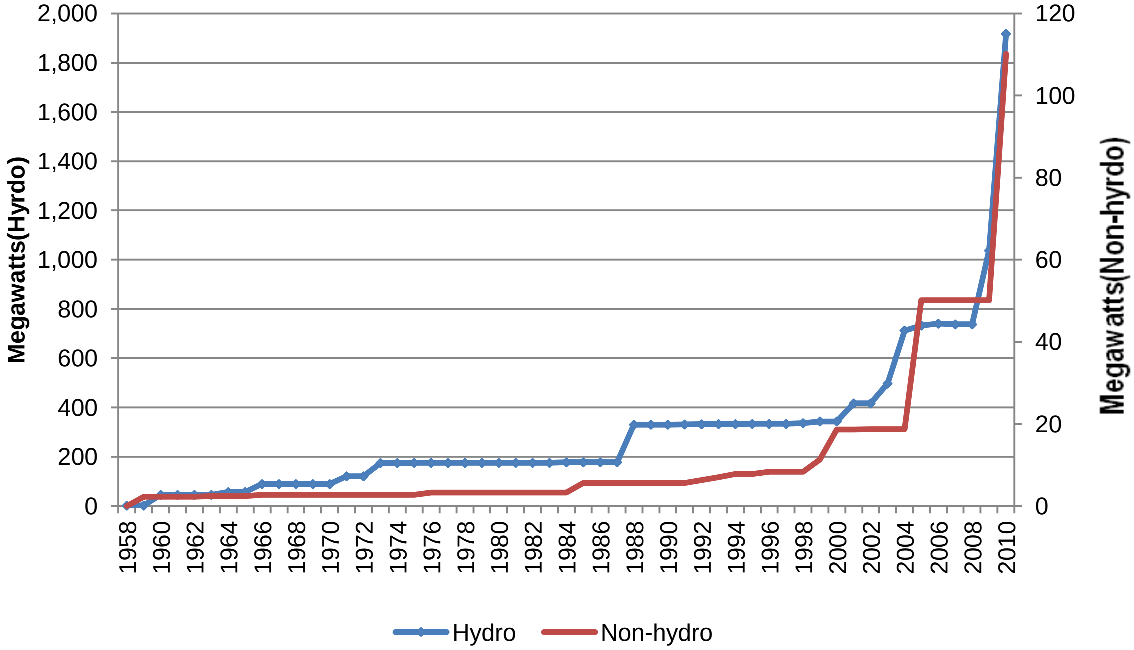
In order to meet the increasing power consumption, the Ethiopian government has been striving to exploit the huge electricity generation potential of the country. Even though the country's total installed capacity from hydropower plants raised very slowly for over half-a-century, from 1958/59 to 2002/03, it has shown a significant rise since 2003/04 (Figure 2.3). In fact, the hydropower generation capacity augmented more during 2009/10 than it did in half-a-century time. The increment in non-hydro generation capacity was also very slow before 2003. In 2003/04 however, it jumped to 119 megawatt (MW) from 32 MW in 2002/03, and reached 179 MW in 2009/10.

Three hydropower plants (Gilgel Gibe II, Tana beles, and Tekeze I) with a combined capacity of 1,180 MW were commissioned in 2009/10 alone, more than doubling the previous installed capacity of the country. Gilgel Gibe II, which doesn't have its own dam, has an installed capacity of 420 MW, Tana Beles has 460 MW, and Tekeze I has 300 MW (EEPCo 2010).

Having been stagnated between 2002/03 and 2005/06, actual electricity production has considerably increased between 2005/06 and 2008/09. It reached 3,684 GWH in 2008/09 from its level of merely 1,606 GWH in 2002/03 (Figure 2.4).

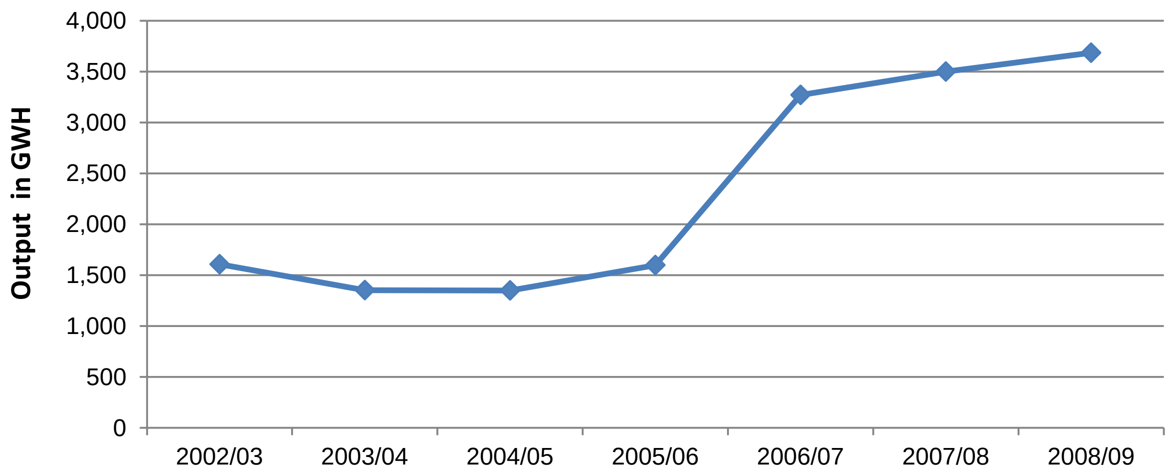
In line with this, EEPCo expected to produce some 5,272 GWH from the old and newly inaugurated plants in 2009/10. That is 2,811 GWH from the old dams, 1,929 GWH from the new dams, and the remaining 532 GWH from government owned and rented diesel generators.

Figure 2.3. Electricity generation (installed) capacity in Ethiopia: 1958–2010



Source: Based on data from EEPCo

Figure 2.4. Yearly actual electric production trend

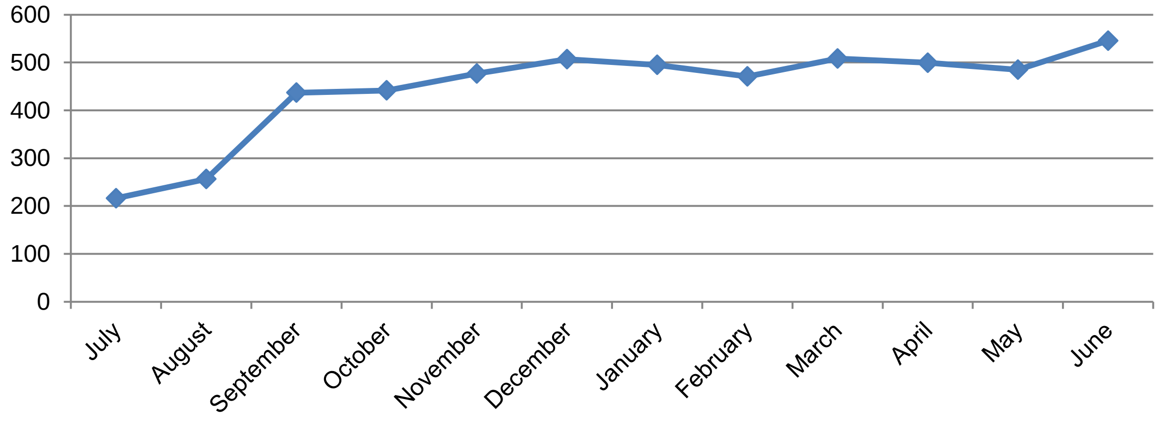


Source: Based on data from EEPCo

The expansion of electric coverage in the country as well as the increasing need from the growing industry and service sectors has created unprecedented electricity demand that exceeded the available electricity generation capacity in the last three-four years. Despite the fact that there is a tremendous rise in installed electricity generation capacity in the past few years, the country has recently faced a chronic power shortage. As mentioned above, this problem was serious during 2007/08 and 2008/09 and even more serious in 2009/10.

There are different dimensions to the electricity problem faced by Ethiopia in 2009/10. While they are related, they have different prime causes and may require different responses. According to EEPCo's expectation, in the fiscal year 2009/10 total electricity output would be the lowest during July and August. This was due to the recorded shortage of rainfall during the *Belg* (minor rainy season) which affected the power generation capacity as the dams had not enough water stored to be used to generate any more power until the next rainy season.

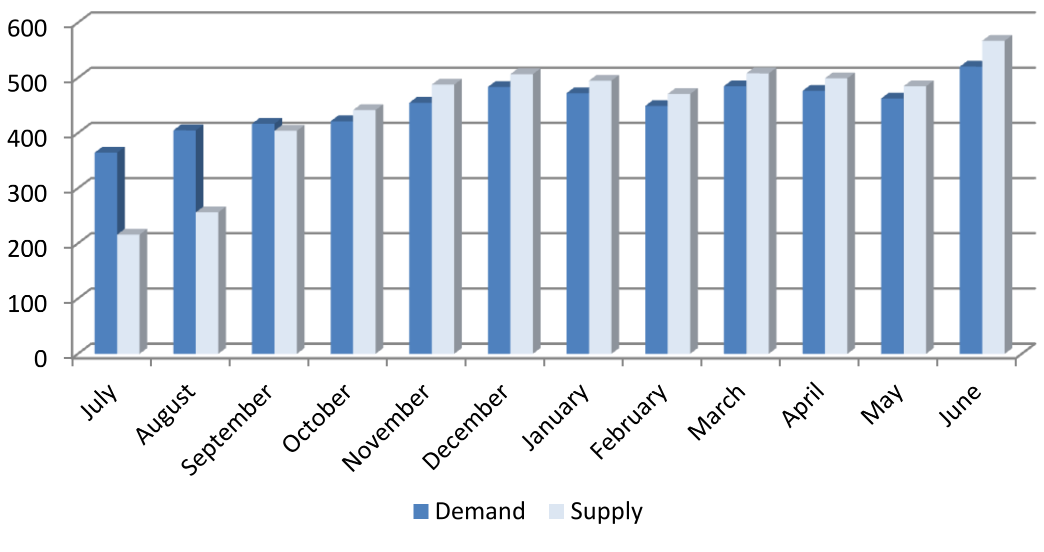
Figure 2.5. Expected monthly electric production (GWH) in 2009/10



Source: Based on data from EEPCo

Based on the expected electricity output and consumption, EEPCo predicted power shortage for July-September 2009/10 only, of which the first two months were expected to be affected the most. The shortage was quantified to be about 149 GWH during July and August, and about 13 GWH during September (Figure 2.6).

Figure 2.6. Expected monthly power shortage (GWH) in 2009/10



Source: Based on data from EEPCo

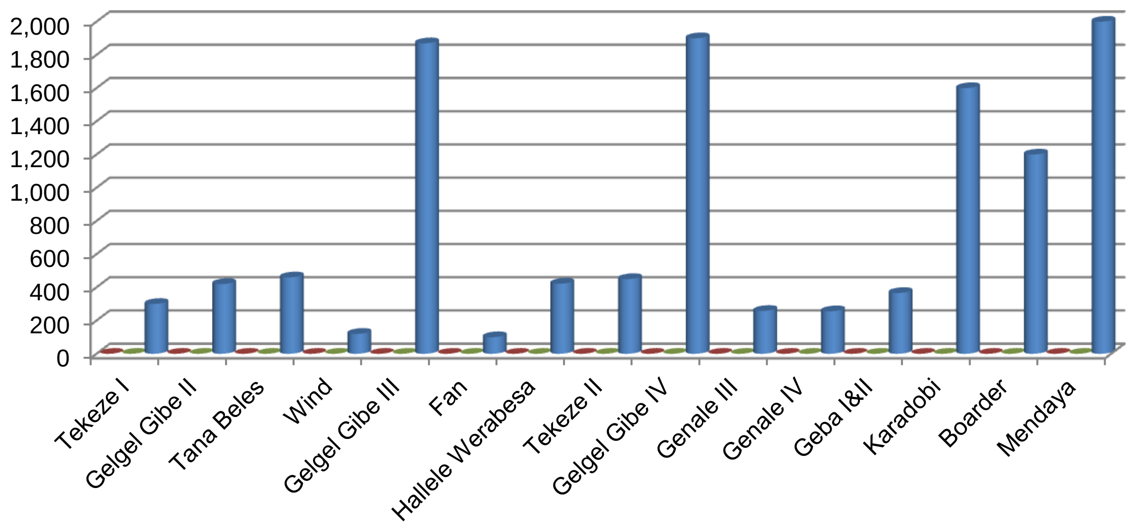
However, the shortage continued even after September because of the delay in completion of the dams and the failure to realize the new Gilgel Gibe II's production due to a technical problem it faced shortly after inauguration. Gilgel Gibe II was expected to produce the largest electricity output (1,135 GWH) in 2009/10. As a result of its failure, the power shortage was further aggravated until the inauguration of Tana Beles in May 2010, which slightly eased the problem.

2.3. Government's measures to mitigate the power shortage

Short term: As an immediate remedy to the power shortage, EEPCo started rationing, though the sectors were not treated equally. The rationing varied from time to time and from sector to sector depending on the intensity of the power shortage and EEPCo's favoring and disfavoring of activities. As the shortage got more serious in 2009/10, some industries, like cement, steel, and crushers, were completely cut off; some were allowed to work limited hours; while some industries that are believed to be 'key industries' (export oriented sectors) were given special privilege in power use. Households, all together using about 34 percent of the total power supply, were rationed with the same intensity as the service sector (i.e. 11.2% power shading).

Long term: In order to get rid of the power shortage problem once and for all, and in an effort to significantly increase access and to speed up its development endeavor, the government has embarked on an ambitious dam building program. In addition to the three already commissioned hydro electric generation plants in 2009/10, Gilgel Gibe III hydropower plant is under construction with an installed capacity of 1,870 MW. Contracts for four more large dams have also been signed and their construction has already started. In addition, there are eight more new power generation plants under project study stage. All the projects are expected to commence production within the coming five to ten years. Once completed, these dams would increase the total power generation capacity of the country by 10,500 MW from less than 1,000 MW in 2008 (EEPCo 2010). Given this, the ever increasing domestic demand is expected to be fully satisfied and the excess to be exported to neighboring countries of Sudan, Kenya, Djibouti, and even Yemen.

Figure 2.7. Power generation capacity of the new plants and projects (MW) in 2009/10



Source: Based on data from EEPCo

3. The model and simulations

Computable general equilibrium (CGE) models combine the abstract Walrasian general equilibrium model with realistic economic data to solve numerically for the levels of supply, demand, and price that secure equilibrium across a specified set of markets (Shoven and Whalley 1984). A CGE model captures the detailed accounts of the circular flows of receipts and outlays in an economy. In addition, it satisfies the equilibrium conditions for all markets simultaneously and is thus useful in analyzing associations between various agents of the economy.

3.1. Model and data

This study uses IFPRI's standard static CGE model[2]. The model is formulated as a set of simultaneous linear and non-linear equations, which define the behavior of economic agents, as well as the economic environment in which these agents operate. This environment is described by market equilibrium conditions and macroeconomic balances.

In the model a multi-stage production technology is adopted. At the top level, value added and intermediate inputs are combined via a Constant Elasticity of Substitution (CES) production technology to produce gross output. Factors of production (value added) are governed in the model by a constant elasticity of substitution (CES) function and producers respond to changes in relative prices and are able to substitute between factors of production subject to constant returns to scale motivated by profit maximization. The intermediate inputs are aggregated in a fixed-share proportion as in a Leontief specification.

The substitution between domestically sold and exported commodities is undertaken based on a constant elasticity of transformation (CET) function with an assumption of imperfect transformability between these two destinations. By doing so, the specification captures any time or quality differences between the two products.

Similarly, the total commodity supply in the domestic market is a composite of the domestically produced and imported. This is captured by a Constant Elasticity of Substitution (CES) aggregation function, imperfect substitutability between imports and domestic output sold domestically as specified in an Armington function (Armington 1969).

Household's consumption demand is given by a linear expenditure system (LES). The model assumes that households maximize utility subject to budget constraints. Households finance their consumption demand from their income.

The model relies on the 2005/06 Ethiopian Social Accounting Matrix (SAM). The SAM is comprehensive and has economy-wide data framework typically representing the economy of the country. The national SAM is disaggregated in 47 activities, 69 commodities, 10 factors, and 8 institutions including 6 households. The SAM also has different taxes, saving-investment, inventory, and rest of the world accounts to show the interaction of different economic blocks.

3.2. System constraints and macroeconomic closures

In order for the model to show systematic workings of a given economy, important system constraints and macro-economic closures need to be set. Accordingly, equilibrium in the goods market requires that demand for commodities equals supply, which is attained through the endogenous interaction of domestic and foreign prices, and the effect that shifts

[2] For detail of the model see Lofgren, H., Harris, R. and Robinson, S. (2001)

in relative prices have on sectoral production and employment, and hence institutional incomes and demand.

On the other hand, factor demand and supply depend on how the relationship between factor supply and wages is defined. Capital is assumed to be fully employed and sector-specific, which implies sector-specific wages adjust to ensure that demand for capital equals total supply. Labor is assumed to have a fixed wage and employment level is determined by the producers' demand for labor.

Similarly, in order to capture the behavior of investors, the government, and the rest of the world, three macro-economic balances or closures for government account balance, current account balance, and savings-investment balance are included in the model. Each closure has different options and underlining alternative assumptions that represent the way institutions operate in the economy can substantively influence the results of the model. The options under these closures are chosen based on their appropriateness to the Ethiopian context.

For saving-investment (S-I) behavior, savings-driven investment closure (instead of investment-driven savings closure) is adopted. Under this closure the savings rates of domestic institutions are fixed, and investment adjusts endogenously to the availability of loanable funds to ensure that savings equals investment spending in equilibrium. The closure option chosen better depicts the country's current consumption, savings, and investment behavior.

Consistent with the fact that direct tax rates have been pretty much unchanged over the past years in Ethiopia, among the government closure options, the one with fixed tax rates and flexible government savings is chosen. This implies the government has to borrow in order to finance its deficit and is constrained in raising taxes to cover additional public spending.

For the current account balance, as Ethiopia adopts a managed-floating exchange rate scheme, it can be assumed that the level of foreign savings is fixed and the exchange rate is flexible. This implies that during shortage of foreign savings, the real exchange rate adjusts simultaneously by depreciating the Birr with respect to USD to reduce spending on imports and increase earnings from export in order to maintain a fixed level of foreign borrowing.
In addition, the domestic producers' price index is chosen as the numéraire and hence all prices in the model are relative to the weighted unit price of producers' initial production bundle.

3.3. The simulations

3.3.1. Electricity shortage simulation

The impact of the electricity shortage on the economy is simulated in a general equilibrium model by introducing productivity loss in each activity as an exogenous shock. The efficiency parameter (α^{va}_{a}) of the production function (equation 1) is used to communicate the direct productivity loss to the model.

(1)

Where QVA_a = *quantity of (aggregate) value-added*
α^{va}_{a}= *efficiency parameter in the CES activity function*
δ^{va}_{fa} = *CES activity function share parameter*
ρ^{va}_{a} = *CES activity function exponent*

$QF_{f,a}$ = *Quantity of factor f used in activity a*

The productivity losses due to the shortage were estimated separately. In estimating the productivity loss of a firm, three factors have been considered: (1) duration of the electricity shortage (ES), (2) the observed intensity of electricity usage (share of a firm's electricity input per unit of output), and (3) substitutability factor (***α***). Substitutability factor is the firms' ability to use alternative energy source or the ability to undertake its major production process without power. This factor is considered because there may be instances where a firm may use little electricity per output but still highly depend on it.

Given this, the percentage decline in output (productivity loss) for an activity is estimated as:

$$PL = ES * \left(Q_{a,elect} / Output \right)^{1/\alpha} \quad (2)$$

Where ***PL*** = *Percentage decline in output (productivity loss)*
ES = *Duration of Electricity Shortage (% of the time)*
$Q_{a,\,elect}$ = *Value of electricity intermediate input*
Output = *Value of Output*
α = *Substitutability factor*

The duration of the electricity shortage is estimated for 2009/10[3] based on the actual rationing schedule of EEPCo. EEPCo had used different rationing programs at different times, based on the level of shortage. In early 2009/10 (July and August) the electricity shortage was severe and rolling blackouts were scheduled every other day throughout the country. During this time, many industries, including cement and steel manufacturing, were completely cut off from electricity supply. The shortage was less severe in middle and late 2009/10 and rolling black outs were less frequent. Throughout the year, EEPCo implemented different monthly rationing plans that reflected the intensity of the shortage.

During the rationing, some export oriented industries, including leather and textile manufacturing, were given special privilege for electricity use. Given the selective favoring and disfavoring, estimating the overall shortage of electricity by industries in 2009/10 requires aggregating the different actual rationing schedules of EEPCo in the fiscal year. During the aggregation of electricity shortage for different types of users, the users' weights in terms of electricity consumption were taken into account for averaging the overall shortage. Accordingly, the average electricity shortage for 2009/10 was estimated to be 12.9 percent of the time in the year.

Since the rationing schedule was not uniform across different users, the electricity shortage faced by different industries also varies. For example because the mining and quarrying activities were disproportionately disfavored during the electricity rationing, the actual electricity shortage endured by these activities is 37.5 percent of the time. On the other hand, the actual shortage of electricity faced by other industries which were favored in the rationing program were below the average shortage of 12.9 percent of the time. For industries such as leather manufacturing which had special privilege in electricity use at all times, electricity shortage level was zero percent.

The second factor considered in the estimation of productivity loss, intensity of electricity usage, is taken from the 2006 Social Accounting Matrix (SAM) of Ethiopia. Looking at activity

[3] 2009/10 is selected as it was the worst hit year of the periods of electricity shortage

level demand, according to the SAM, activities as agriculture, fetching water, and real estate do not use electricity as intermediate input. All the other activities use electricity with different levels of intensity in relation to their outputs. Industries generally use higher values of electricity per unit of output than services. Among the activities in the industry sector, construction and manufacturing of electrical equipments have the highest output per electricity input, while mining and quarrying and manufacturing of mineral products have the least output per unit of electricity input (see Table 3.1).

Table 3.1. Electricity use and electricity productivity in different activities of the industrial sector

Activity	Electricity use ('000 Birr)	Electricity productivity Output/Input
Grain mill production	13,272.4	49.4
Other food manufacturing	37,075.9	72.3
Beverage manufacturing	17,648.1	103.8
Sugar manufacturing	5,383.2	214.9
Tobacco manufacturing	769.2	280.7
Paper products manufacturing	12,694.9	55.0
Mineral products manufacturing	58,749.0	19.9
Basic metal manufacturing	12,916.0	154.4
Chemicals manufacturing	26,228.7	61.1
Machinery and Equipment manufacturing	94.7	236.5
Electrical Equipment manufacturing	55.1	1,981.4
Textile manufacturing	37,043.7	36.5
Leather manufacturing	11,315.9	94.5
Wearing apparel	1,425.2	248.2
Vehicle manufacturing	1,202.3	342.0
Wood manufacturing	1,926.7	55.9
Other manufacturing	3,691.2	425.6
Mining and Quarrying	37,876.4	19.3
Construction	7,270.0	2,922.2

Source: Based on data from 2005/06 EDRI SAM

Different rationing alternatives under the existing power supply constraint were tested and analyzed in a general equilibrium.

Alternative Electricity Rationing Scenarios

Given the total average of 12.9 percent electricity shortage during 2009/10, different rationing scenarios, favoring and disfavoring selected activities, can be compared based on different criteria of interest. Accordingly, in this study the government's rationing strategy is simulated and compared with three other deemed important and practical alternative strategies. With a fixed electricity supply in the year, favoring a particular industry in any of the rationing alternatives entails disfavoring another industry.

In all the alternative scenarios, the service sector and households are excluded from favoring/disfavoring as it is practically difficult to target them in administering a unique rationing program, although they are major users of electricity.

Scenario 1 - Rationing that favors export sectors and disfavors selected sectors (GOVRAT)

This rationing alternative is similar to the way government distributed the power shading. The actual rationing for the year can be summarized as:

- Exempting textile and leather manufacturing from the power shading;

- 37.5% power shading in the mining and quarrying activities ;
- 31.8% power shading in basic metal manufacturing ;
- 19.3% power shading in mineral products and chemical manufacturing ; and
- 11.2% power shading in all the remaining activities.

Scenario 2 - Uniform rationing (UNIRAT)
Another option considered for accommodating electricity power shortage is to ration all economic sectors equally without any favor or disfavor. This alternative is equivalent to electricity shading for 12.9 percent of the time in all activities which is the weighted average shortage as discussed above.

Scenario 3 - Rationing that favors export sectors (EXPRAT)
This alternative favors export oriented activities in the same way as the government rationing strategy, but uniformly disfavors the rest of the activities. This is equivalent to:

- Full electricity supply to textile and leather industries; and
- 13.5% electricity shading in all the other activities.

Scenario 4 - Rationing that favors activities of high electricity productivity (PRODRAT).
The other alternative to reduce output loss due to electricity shortage is to favor activities with high electricity productivity and disfavor activities with relatively low electricity productivity (see Table 3.1). In doing this, industrial activities are categorized into three levels of electricity productivity: high, medium, and low. High electricity productivity activities are favored, low electricity productivity activities are disfavored and medium electricity productivity activities are moderately rationed. In this alternative, in addition to rationing based on electricity productivity, export oriented activities are also favored. This alternative is equivalent to:

- 100% electricity supply to textile and leather manufacturing;
- 100% electricity supply to activities whose output per unit of electricity is higher than 240, including electrical equipments manufacturing, vehicles, tobacco, wearing apparel etc.
- 15.6% power shading on activities whose output per unit of electricity is lower than 65. These activities include mining and quarrying, flour manufacturing, paper products, chemicals, wood manufacturing, etc.
- Average (12.9%) power shading in all the remaining activities with medium level of electricity productivity.

3.3.2. Electricity investment simulation

Under this simulation, the country's current step in increasing electricity power generation, the intent to export, and the augmented domestic electricity consumption is simulated. The output rise is estimated for the investments already made since 2006 and investments planned to be undertaken until 2015. As the analysis is based on a static CGE model, the investment during the 9 years is calibrated in the model as if it occurs in a single period.

To simulate the electricity production increment as a result of the investment, return on capital of the electricity activity was raised by an amount that would achieve planned electricity production. The increased production is in line with the most recent government's plan to increase production, domestic consumption, and export. On the other hand, to capture government's rural electrification program, rural households' electricity consumption is increased by raising the households' autonomous consumption parameter in the consumption function.

4. Results and discussion

4.1. Electricity rationing

The simulation results show that the power shortage during 2009/10 has affected the economy significantly. The overall output loss based on government's actual rationing scheme is estimated to be around 3 percent of GDP. The effect of the shortage is negative in all activities, manufacturing being the most affected with an output loss of 10.3 percent. On the other hand, service and agriculture sectors are relatively less affected, with output loss of 2.3 and 2.7 percent respectively (Table 4.1).

The larger percentage loss of output in manufacturing is due to the higher importance of electricity input in the sector. The output loss in activities that are directly affected by the shortage has also resulted in an indirect output loss in other activities through forward and backward linkages. The output loss in agricultural activities for example is purely an indirect impact because agriculture does not rely on electricity input in its production.

Table 4.1. Output and output loss by activity, based on EEPCo's actual electricity rationing

Sector	Base Value added (Billion Birr)	Electricity shortage Value Added (Billion Birr)	Output loss (% change)
Agriculture	58.8	57.2	-2.70
Industry	14.1	13.0	-7.38
Manufacturing	5.8	5.2	-9.90
Services	49.4	48.3	-2.26
Total GDP	122.2	118.5	-3.06

Source: Authors' computation based on simulation result

The impact of the electricity shortage on external trade, domestic investment expenditure, and output by major activities under alternative rationing strategies are presented in Tables 4.2 and 4.3. The details of output loss by activity are also presented in Annex Table A.1. Based on the result, the impact of the shortage on output, external trade, and investment is slightly different under the various rationing alternatives. In every consideration, the government's rationing scheme (GOVRAT) is slightly worse than all the other alternatives. Despite government's measure in favoring export oriented activities, total export reduced the most under this alternative. This shows that favoring a particular industry alone with less regard to the activities that are closely linked to the industry may not bring intended results. The GDP loss in the actual government rationing scheme was also the largest (3.06 percent) among the alternatives. The high GDP loss was the result of the disproportionate disfavoring of selected activities that brought about big direct output loss with significant negative spillover in other activities.

Since manufacturing industries, except textile and leather, are severely disfavored in the government rationing scheme, the output loss in manufacturing under GOVRAT is the highest among all alternatives. In terms of total output loss, uniform power rationing across all activities (UNIRAT) would have reduced the output loss to 2.73 percent of GDP. The decline in investment expenditure is also the least under uniform rationing. On the other hand, favoring export oriented activities while uniformly distributing the shortage in all the remaining activities (EXPRAT) further reduced the GDP loss to 2.71 percent. The export decline in this alternative is also smaller than GOVRAT and UNIRAT. The lower output loss under EXPRAT compared to UNIRAT is due to the stronger linkages of the textile and leather industries to the rest of the economy that induce stronger output effect. Favoring the export sector and activities with high electricity productivity simultaneously (PRODRAT) would also have reduced the negative impact of the electricity shortage in the economy, to 2.71 percent, as in EXPRAT. The export decline in this alternative is smaller than all the other alternatives.

Table 4.2. Results under different alternative scenarios

	BASE (billion Birr)	GOVRAT (% change)	UNIRAT (% change)	EXPRAT (% change)	PRODRAT (% change)
GDP at Constant Prices	122.22	-3.06	-2.73	-2.71	-2.71
EXPORTS	16.80	-5.49	-5.42	-5.39	-5.28
IMPORTS	-47.00	-1.96	-1.93	-1.92	-1.88
INVESTMENT	28.20	-4.10	-3.50	-3.60	-3.60

Source: Authors' computation based on simulation result
Note: See above for the description of the different scenarios: GOVRAT, UNIRAT, EXPRAT, and PRODRAT.

Table 4.3. Output loss by major activity under different rationing alternatives

	BASE (billion Birr)	GOVRAT (% change)	UNIRAT (% change)	EXPRAT (% change)	PRODRAT (% change)
Agriculture	58.8	-2.70	-2.40	-2.36	-2.38
Industry	14.1	-7.38	-6.07	-5.98	-6.06
Manufacturing	5.8	-9.90	-9.20	-8.76	-8.67
Service	49.4	-2.26	-2.17	-2.21	-2.15
Total GDP	122.2	-3.06	-2.73	-2.71	-2.71

Source: Authors' computation based on simulation result
Note: See above for the description of the different scenarios: GOVRAT, UNIRAT, EXPRAT, and PRODRAT.

The welfare impact in terms of household consumption also slightly varies among the different rationing alternatives (Table 4.4). Overall, household consumption declined by 2.41 percent under government's actual rationing scheme (GOVRAT) which is the highest decline of all the alternatives. Under this rationing scheme, the decline in consumption is the highest in almost all household types. On the other hand, favoring export oriented activities while uniformly distributing the shortage in all the remaining activities (EXPRAT) or favoring export oriented activities together with high electricity productive activities (PRODRAT) would result in the least household consumption loss. The reduction of household consumption is largely related with the decline in GDP. The household consumption reduction under GOVRAT for example is the highest among the other alternatives because the GDP loss under this alternative is also the highest.

Table 4.4. Consumption change by household type under different rationing alternatives

	BASE (billion Birr)	GOVRAT (% change)	UNIRAT (% change)	EXPRAT (% change)	PRODRAT (% change)
Rural poor	19.1	-2.12	-1.92	-1.91	-1.92
Rural non-poor	59.4	-2.66	-2.38	-2.34	-2.33
Urban poor	3.9	-1.85	-1.92	-1.84	-1.87
Urban non-poor	21.5	-2.10	-1.96	-1.92	-1.92
Total households	103.8	-2.41	-2.19	-2.15	-2.15

Source: Authors' computation based on simulation result
Note: See above for the description of the different scenarios: GOVRAT, UNIRAT, EXPRAT, and PRODRAT.

To conclude, favoring the export sector and activities with high electricity productivity simultaneously (PRODRAT) is the best alternative in all considerations except in domestic investment expenditure where uniform rationing had the least investment reduction.

4.2. Investment on electricity

The investment simulation on electricity and the associated electricity export show that the government's investment will have a significant growth contribution to the economy with GDP increment of about 6.1 percent.

The estimated GDP growth is expected to come mainly from the output growth in the electricity generation which is expected to grow by more than eight fold. The investment, however, has a negative effect on the other activities with an output loss between 0.1 percent in the service sector and 3 percent in agriculture and manufacturing.

Table 4.5. GDP by major activities under electricity investment scenario

GDP by sector	BASE (2005/06) (Billion Birr)	Investment in Electricity Scenario (Billion Birr)	Change (%)
Agriculture	58.78	56.97	-3.1
Industry	14.05	23.32	66.0
Electricity	1.12	9.72	765.1
Manufacturing	5.77	5.60	-2.9
Services	49.39	49.35	-0.1
Total	122.22	129.64	6.1

Source: Authors' computation based on simulation result

Table 4.6. Export earnings from major activities under electricity investment scenario

	BASE (2005/06) (Billion Birr)	Investment in Electricity Scenario (Billion Birr)	Change (%)
Agriculture	5.6	3.5	-37.1
Manufacturing	2.4	1.7	-28.2
Services	6.8	6.2	-8.4
Electricity	0.0	9.6	
Total Exports	14.7	21.0	43.2
Imports	-47.0	-64.7	37.6

Source: Authors' computation based on simulation result

The decline in agricultural output and export is the result of the induced real exchange rate appreciation which reduces the competitiveness of the country's current export commodities in which agricultural products constitute a significant share. Manufacturing output would also decline as a result of the real exchange rate appreciation. As manufacturing forms only a small share of total export, the output decline in the manufacturing sector is supposed to come from the sector's loss of competitiveness in the domestic market. Imported manufacturing commodities would become cheaper and adversely affect production of competing locally manufactured products. This Dutch disease effect is expected to come from earnings of electricity export that bring about a 14 percent appreciation of the real exchange rate. Export of services is also expected to decline significantly even though the rate of decline is smaller than agricultural and manufacturing exports.

The decline in agricultural, manufacturing, and service output, and the rise in electricity production would bring a significant change in output structure. Electricity would take about 7.5 percent of the country's GDP (from its previous level of only 0.9 percent), while the share of agriculture, manufacturing, and services would decline.

Export earnings from electricity after the investment are estimated at 9.6 billion Birr, which would be about 46 percent of total export of goods and services. This would increase total export earnings by 43.2 percent. Since export earnings from electricity significantly increase while exports of other goods decline, the share of electricity exports from total merchandize exports is expected to shoot up to 64.9 percent. Electricity, becoming the first major export earner, is expected to bring a significant shift in export structure of the country. Furthermore, as a result of the relative abundance of foreign exchange and the associated appreciation of the real exchange rate, imports are expected to rise by 37.6 percent.

5. Summary and conclusion

Using a static CGE model and based on the 2005/06 Ethiopian SAM, the study evaluated the economy wide impact of electricity shortage during 2009/10 and compared the government's rationing scheme with three alternative rationing scenarios. The study also assessed the effect of government's investment in expansion of electricity generation for both domestic consumption and export.

The results show that the electricity shortage in Ethiopia has brought a significant adverse effect on the economy with an output loss of 3.1 percent of GDP during 2009/10. The impact was negative in all activities. Though the impact was higher in activities that use a higher volume of electricity, activities that do not use electricity have also been affected through both forward and backward linkages with the other activities.

Different rationing alternatives had different impacts. The impact of the shortage on output, external trade, and investment is slightly worse under the government's rationing scheme compared to the other alternatives. Despite the government's measure in favoring export oriented activities, total export reduced the most under the applied rationing scenario. The GDP loss in the actual government rationing scheme was also the largest among the alternatives. Overall, favoring the export sector together with high electricity productivity sectors would have brought better result in terms of reduced output loss and exports, while uniform rationing had the least investment reduction.

The simulation on investment in electricity generation and electricity export shows that the government's investment plan will bring a 6.1 percent rise in GDP. The output growth is expected to come from the electricity generation. The investment, however, would result in output reduction in all the other activities due to loss of competitiveness as a result of the induced real exchange appreciation following the foreign exchange inflow from electricity export.

Electricity export would increase total export earnings by 43.2 percent. With the decline in the exports of mainly agricultural and manufactured commodities, the investment would bring about a significant shift in export structure, with electricity becoming the first major export item.

However, as the static version may not capture the inter-temporal economic linkages and transformations of the investment simulation, further study should be undertaken with a recursive dynamic CGE model. Another potential path to explore would be explicitly including energy –as a commodity-factor– into the production function.

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Annex

Annex Table A.1. Output by activity (billion Birr) under different electricity rationing alternatives

ACTIVITY	BASE	GOVRAT	UNIRAT	EXPRAT	PRODRAT
teff	4.45	4.33	4.36	4.36	4.36
maize and wheat	8.09	7.83	7.87	7.87	7.86
non-traded agriculture	18.36	17.80	17.87	17.87	17.87
export crops	10.29	10.04	10.03	10.02	10.03
livestock	17.60	17.20	17.24	17.27	17.26
mining and quarrying	0.67	0.49	0.60	0.60	0.59
other food manufacturing	0.69	0.64	0.63	0.64	0.64
dairy manufacturing	0.04	0.04	0.04	0.04	0.04
grain mills	0.17	0.15	0.15	0.15	0.15
flour manufacturing	0.51	0.46	0.45	0.45	0.44
sugar manufacturing	0.54	0.49	0.49	0.48	0.49
beverage manufacturing	0.84	0.78	0.78	0.77	0.77
tobacco manufacturing	0.12	0.12	0.12	0.11	0.12
textile manufacturing	0.66	0.61	0.60	0.61	0.61
wearing apparel manufacturing	0.18	0.17	0.17	0.17	0.17
leather manufacturing	0.27	0.27	0.25	0.27	0.27
wood and furniture manufacturing	0.07	0.06	0.06	0.06	0.06
paper and printing manufacturing	0.21	0.19	0.19	0.19	0.18
chemical manufacturing	0.37	0.30	0.33	0.32	0.32
mineral prod. Manufacturing	0.26	0.22	0.24	0.24	0.24
basic metal manufacturing	0.51	0.39	0.46	0.46	0.46
machinery manufacturing	0.01	0.01	0.01	0.01	0.01
electrical equip. manufacturing	0.01	0.01	0.01	0.01	0.01
vehicle manufacturing	0.09	0.09	0.09	0.09	0.09
other manufacturing	0.21	0.20	0.20	0.20	0.21
electricity	1.12	1.11	1.11	1.11	1.11
water	1.17	1.10	1.10	1.09	1.09
construction	5.32	5.12	5.15	5.14	5.14
trade	13.82	13.27	13.33	13.33	13.34
hotels	2.53	2.38	2.37	2.37	2.37
transport and comm.	6.35	6.26	6.25	6.24	6.25
financial services	2.29	2.12	2.11	2.10	2.11
real estate	9.66	9.65	9.65	9.65	9.65
public administration	5.96	5.95	5.95	5.95	5.95
education	4.29	4.26	4.26	4.26	4.26
health	1.06	1.04	1.04	1.04	1.04
other services	3.43	3.35	3.36	3.36	3.36
GDP	122.22	118.49	118.89	118.90	118.91

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