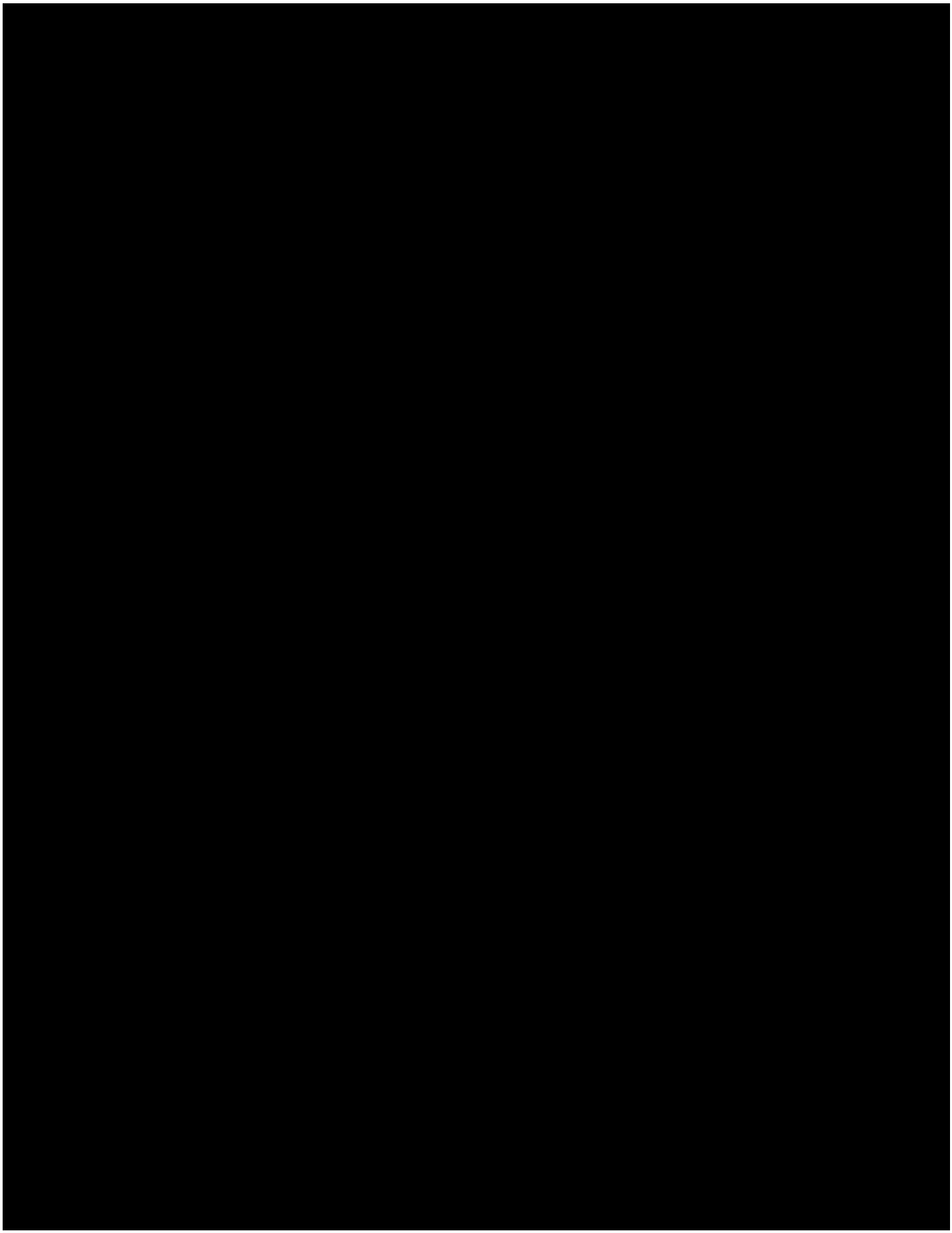


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Investing in Electricity, Growth, and Debt Sustainability: The Case of Lesotho

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Abstract

This paper analyses a large public investment in a construction of a hydropower plant in Lesotho and its implications on the growth and debt sustainability. The paper employs an open economy dynamic general equilibrium model to assess the benefits of a large public investment through growth-enhancing increase in domestic energy supply and receipts from selling electricity abroad to ease the fiscal burden, which is often associated with big investment projects. During the transition (construction stage), various financing options are explored: increase in the public debt, increase in domestic revenue (fiscal adjustment), and combination. The calibration matches Lesotho's data and it captures the project's main challenges regarding the project costs. Moreover,the key remaining issue is the agreement with South Africa to purchase sufficient amount of electricity to allow the potential plant to run at a high capacity. We find that, the project can lead to sizable macroeconomic benefits as long as costs are relatively low and demand from South Africa is sufficiently high. However, the risks for the viability of the project are high, if these assumptions are violated.

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I. Introduction

Despite achieving a relatively strong economic growth over the last several years, Lesotho continues to face large poverty and high unemployment. This growth was largely driven by the growth in the public sector with central government's expenditures reaching over 60 percent of GDP, including about 25 percent of GDP for wages. This public sector expansion was achieved mainly due to strong, albeit volatile, inflows in the form of revenues from Southern Africa Customs Union (SACU), which peaked at 30 percent of GDP in recent years. It is expected that in 2016/17 these revenues will fall sharply, putting pressure on government finances. It remains to be seen how sustainable this level of SACU revenues will be in the long run and whether Lesotho would face a long-term resource constraint in future.

The government identified development of the private sector as a main priority in tackling the problems of poverty and unemployment. Measures have been undertaken to improve the business environment. Moreover, the country is facing large infrastructure gap, which also creates substantial impediments for successful private sector development. In the National Strategic Development Plan (NSDP) adopted in [2012], the government identified public investments in infrastructure as one of its key policy priorities. However, it appears that little progress has been achieved in this area since then. Jointly with external partners, there have been some developments in water and hydro sectors.

Being a mostly mountainous country, Lesotho possesses large water resources, which in the past remained largely underutilized. To tap into these resources, Lesotho agreed with South Africa on developing a network of reservoirs and tunnels to supply water to Gauteng, the most populous and industrial area of South Africa. The first phase of the Lesotho Highlands Water Project (LHWP), which began in late [1980s], involved the construction of Katse dam (completed in 1998) and Mohale dam (completed in 2002) and supply of water to South Africa commenced, for which Lesotho is receiving payments of about US$ [70] million per year. Also, as part of the first phase a hydropower plant was built at Muela Reservoir with a maximum nominal generating capacity of 72 MW to supply electricity domestically. Apart from other mini hydropower plants (total capacity of 3MW), this became the first relatively large power station in Lesotho. Previously, most of the supply of electricity came from imports.

The second phase of the LHWP commenced in 2014 and involves the construction of Polihali Dam as a first stage. Under the second phase of the project, it is also envisaged the construction of the hydro-power station. Moreover technical feasibility study entails building of an additional dam at Kobong together with a pump-storage power plant with the potential capacity of 1,200MW. Given the specificity of a pump-storage facility, the main destination for the supply of produced electricity would likely be neighboring South Africa and would require long-term power purchasing agreement between the two countries. In additional to the purchasing price, the financial feasibility of the project will critically depend on how much electricity South Africa will be needing, which will determine capacity utilization factor. It is important that before the project could begin, an agreement stipulating these elements should be reached between Lesotho and its neighbor. The authorities are currently undertaking economic and financial studies of project feasibility. This work is supported

by the World Bank and is expected to be finalized in [2016]. The paper assumes a fixed share of electricity produced would be sold to South Africa and the remaining consumed domestically. All electricity purchases would come from South Africa.

On the surface, the project appears beneficial to Lesotho in terms of providing additional supply of electricity for potential growth. More importantly, the project would potentially become a large source of income for the country and provide additional infrastructure much needed to boost private sector development. The financial and economic viability of the project does depend on a several critical factors. Project of this complexity and size naturally runs the risk of cost overruns, which could create additional burden for the country. According to the agreement, Lesotho authorities are responsible for securing financing for the project. In current environment, most of financing would likely come from non-concessional sources and is highly sensitive to interest rates. Large and unexpected increase in project or financing costs could jeopardize financial viability of the project. Given the large size of project for the country and its potential financial burden on government finances, it is important to evaluate these financial and economic risks and their impact on the project's feasibility.

The main purpose of this paper is to assess various scenarios and whether this project will be feasible from macroeconomic and debt sustainability standpoint as well as identify key bottlenecks/risks that need to be minimized by taking appropriate early actions. To do so we develop a variant of the model developed by Buffie et al. (2012). This is a full-fledged dynamic macroeconomic model that allows for investment in infrastructure and government financing through concessional, commercial, or domestic debt, and/or fiscal adjustment. Specifically we extend the model to tailor it to Lesotho. We incorporate a publicly owned electricity sector which has sales both to domestic firms and foreign costumers. In the model, increases in domestic energy supply are growth-enhancing while receipts from selling electricity abroad can ease the fiscal burden (tax increases), which is often associated with big investment project. Still, in the transition, debt as well as taxes can rise substantially to pay for this investment.

In addition to Buffie et al. (2012), other papers employ a similar structural framework to analyze public spending impacts on growth and public debt in developing economies. The closest work to our own is the paper by Issoufou et al. (2014) on Senegal. They also analyze public investment in the electricity sector, the main difference is that their model does not allow export of electricity which play a major role in Lesotho's choice and employs two different production functions for energy. It is important to note that despite coming from different data, their calibration for the use of electricity in the production side of the economy is similar to ours. Other papers apply the original model to low income countries and highlight its usefulness to study various challenges that these countries face in scaling up public investments; examples include Andrle et al. (2012) for Togo, Mu (2012) for Cape Verde, and Clark and Rosales (2013) for Liberia among others. The framework we propose could be potentially useful for many other developing countries which could embark in sizable investments in electricity exporting activities, such as the Democratic Republic of Congo, Kyrgyzstan, and Tajikistan among others.

The methodology employed in this paper complements the WB-IMF's standard Debt Sustainability Analysis (DSA) framework. The DSA is a powerful and widely used tool for debt sustainability

analysis, however it is not designed to incorporate explicitly details of specific projects, such as LHWP, and use implicit assumptions on the project outcomes. On the other hand, by using explicit assumptions on the economy and the project, we can assess the direct and indirect macroeconomic channels through which the project affects the debt and growth outlook of the economy. We believe this addresses the point by Wyplosz (2007) on the fact that growth benefits of public investment projects can ease the debt burden.

The remainder of the paper is structured in four sections. Section II presents the theoretical model. In section III and IV we calibrate the model to Lesotho data and analyze the results of the simulations under various assumptions. Section V concludes.

II. The Model

The model is an open-economy dynamic general equilibrium model based on Buffie et al. (2012). The main innovation in our model is the introduction of a public energy sector that produces and sells electricity both domestically and abroad according to a predetermined rule.

A. Firms

A.1. Tradable and Nontradable Sectors

The economy produces two types of goods, traded goods (x) and non-traded goods (n). Firms produce final output $q_{j,t}$ ($j = x, n$) using labor $L_{j,t}$, private capital $k_{j,t-1}$, energy $E_{j,t}$ and public effective infrastructure $\tilde{z}_{t-1}$ using a Cobb-Douglas technology.

$$q_{x,t} = A_{x,t} \left(\tilde{z}_{t-1}\right)^{\psi_x} \left(k_{x,t-1}\right)^{\alpha_x} \left(E_{x,t}\right)^{\beta_x} \left(L_{x,t}\right)^{1-\alpha_x-\beta_x}, \tag{1}$$

and

$$q_{n,t} = A_{n,t} \left(\tilde{z}_{t-1}\right)^{\psi_n} \left(k_{n,t-1}\right)^{\alpha_n} \left(E_{n,t}\right)^{\beta_n} \left(L_{n,t}\right)^{1-\alpha_n-\beta_n}. \tag{2}$$

Note that infrastructure is a public good, not firm-specific, and enters the production function with increasing returns to scale. On the other hand, electricity is firm-specific and exhibits a constant return to scale feature of private goods.
The firm productivities A_j are composed of the following factors:

$$A_{x,t} = a_x \left(\frac{q^I_{x,t-1}}{\bar{q}^I_x}\right)^{\sigma_x} \left(k^I_{x,t-1}\right)^{\xi_x},$$

and

$$A_{n,t} = a_n \left(\frac{q^I_{n,t-1}}{\bar{q}^I_n}\right)^{\sigma_n} \left(k^I_{n,t-1}\right)^{\xi_n}.$$

The first element a_j is the traditional exogenous productivity factor. The other two elements are externalities which are specific to each sector. $\left(\frac{q^I_{j,t-1}}{\bar{q}^I_j}\right)^{\sigma j}$ represents a learning by doing externality as discussed in Berg et al. (2010). $\left(k^I_{j,t-1}\right)^{\xi_j}$ is Arrow (1962) externality, which depends on private capital accumulation. Both externalities are marked by the superscript I, which denotes a variable that does not enter firms' maximization problem.

Factors market is competitive in this model. The result from the maximization process of firms yields:

$$P_{n,t}(1-\alpha_n-\beta_n)\frac{q_{n,t}}{L_{n,t}} = w_t, \tag{3}$$

$$P_{x,t}(1-\alpha_x-\beta_x)\frac{q_{x,t}}{L_{x,t}} = w_t, \tag{4}$$

$$P_{n,t}\alpha_n\frac{q_{n,t}}{k_{n,t-1}} = r_{n,t}, \tag{5}$$

$$P_{x,t}\alpha_x\frac{q_{x,t}}{k_{x,t-1}} = r_{x,t}, \tag{6}$$

$$P_{n,t}\beta_n\frac{q_{n,t}}{E_{n,t}} = P_{e,t}, \tag{7}$$

and

$$P_{x,t}\beta_x\frac{q_{x,t}}{E_{x,t}} = P_{e,t}, \tag{8}$$

Labor and electricity can be reallocated between sectors, determining the common wage w appears in (3) and (4) and the common domestic price of electricity P_e appears in (7) and (8). Note that the domestic and external electricity markets are segmented, with the domestic price responding only to domestic conditions and the foreign one being exogenous to the model.
Capital exhibits a different behavior as it is sector-specific, however the rental rates r_x and r_z can be different only on the transition path. Once k_x and k_n have converged to the equilibrium, the interest rate converge as well.

A.2. Energy Sector

The economy features a state owned electricity sector (including all phases: generation, transmission, and distribution), whose cost of running and investments are financed through the general government budget (i.e. they are included in the aggregate budget constraint).
As mentioned, the second phase of the Lesotho Highlands Water Project includes a plan to build a pump storage hydroelectric power station, which will be connected to the South African grid. Widely used across the world, this type of power plants in essence works as a battery for the grid. It exploits the intertemporal differences in the demand for electricity (e.g. peak hours versus non-peak hours) and the difficulties to vary production to match these type of variations in the demand (many technological

processes behind electricity production cannot be easily turned on and off). How does it work in practice? First, when the price is low (usually at night and on the weekends) the plant buys electricity and uses it to pump up water from a reservoir to a second reservoir at a higher altitude. Second, during peak hours, when the electricity price is high, the water is run down to the lower reservoir to produce electricity, which is sold at a higher price (peak tariff rates). While such technologies consume more electricity than is produces, what makes them feasible is the sufficient spread between the peak and non-peak prices[1]. The ratio between the electricity used and produced is defined as $1 + loss_factor$.
Large proportion of the electricity production from this investment is expected to be exported to South Africa and the details of a possible agreement are still subject to negotiations. For the model we take a fixed share of electricity to be sold to South Africa and the remaining consumed domestically. While electricity used to pump water up would be purchased from South Africa.
Lesotho's existing conventional hydroelectric power production satisfies some of the current electricity consumption in the country.

The state run energy company uses the energy-related effective capital stock $\tilde{k}_{e,t-1}$ to produce electricity. Given the low labor intensity of the energy sector (it employs less than 0.4% of the Basotho labor force[2]), we make the simplifying assumption that labor is not used in this production function. Electricity production is determined by the size of the effective capital stock. Given the specificity of a pump storage, its production technology differs from a conventional hydro also in their differences in the capacity factor[3]:

$$q_{e,t} = a_{e,0}\tilde{k}_{e,0} + a_e\theta(\tilde{k}_{e,t-1} - \tilde{k}_{e,0}) \tag{9}$$

Where $a_{e,0}$ is the initial (conventional) technology, a_e is the new technology associated with a capacity factor of one, θ is the capacity factor.

The full initial electricity output and a γ fraction of the new output is sold in Lesotho's domestic market and the remaining $(1-\gamma)$ of the additional electricity to the South African market.

$$q_{e,t}^{Domestic} = q_{e,0} + \gamma(q_{e,t} - q_{e,0})$$
$$q_{e,t}^{Foreign} = (1-\gamma)(q_{e,t} - q_{e,0})$$

The price charged to the domestic costumers equals to $P_{e,t}$, the one charged to South Africa is $P_{e,t}^{sell}$, and the price paid to South Africa to pump water up equals to $P_{e,t}^{buy}$. For every kWh of electricity produced a pump storage hydroelectric power station needs to use $(1+loss_factor)$ kWh of electricity. Net sales of electricity by the sector equals to:

$$P_{e,t}q_{e,t}^{Domestic} + P_{e,t}^{sell}q_{e,t}^{Foreign} - P_{e,t}^{buy}(q_{e,t} - q_{e,0})(1 + loss_factor)$$

[1]More detailed explanations on pump storage plants can be found in Yang (2012), Makarechian (1996)
[2]Data from BOS (2008)
[3]How many hours and at what power the turbines are active.

Buy and sell prices from and to South Africa are exogenous, and can be designed as constants, staggered fix prices, or exogenous autoregressive processes. On the other hand, the domestic electricity price is endogenously determined in the Lesotho's electricity market.

It is also useful to define the profit per unit of electricity sold to South Africa $P^*_{e,t}$[4] as it can be used to determine the total Lesotho GDP, given that domestic electricity is consumed as an intermediate input only:

$$ny_t = P_{x,t}y_{x,t} + P_{n,t}y_{n,t} + P^*_{E,t}q^{Foreign}_{e,t} \tag{10}$$

A.3. Capital Goods Production

All capital goods are produced according to a Leontief production function. To build one unit of private capital, infrastructural capital, or electricity capital (the dam, the power plant, and all the ancillary works) it is necessary to combine one imported machine with a_j $(j = k, z, ke)$ units of non-traded input such as construction.
This technology implies these supply prices for capital goods:

$$P_{k,t} = P_{mm,t} + a_k P_{n,t}, \tag{11}$$

$$P_{z,t} = P_{mm,t} + a_z P_{n,t}, \tag{12}$$

and

$$P_{ke,t} = P_{mm,t} + a_{ke} P_{n,t}, \tag{13}$$

where P_n is the (relative) price of the non-traded good and P_{mm} is the (relative) price of imported machinery.

The capital stocks evolve according to the law of motion presented in subsections B.1. and C.1..

B. Consumers

The model assumes two types of economic agents: savers $\mathfrak{s}$, who can save part of their income and can trade in assets, and non-savers (or hand-to-mouth) $\mathfrak{h}$, who consume their income entirely and cannot save or borrow. Agents supply a fixed amount of labor. Fractions of savers and non-savers in the economy are fixed, with a savers for each non-saver. The two types of agents share consumption preferences; the composite CES consumption good consists of domestic traded goods $c^i_{x,t}$, domestic non-traded goods $c^i_{n,t}$, and imported traded goods $c^i_{m,t}$ for $i = \mathfrak{s}, \mathfrak{h}$.

$$c^i_t = \left[\rho_x^{\frac{1}{\epsilon}} \left(c^i_{x,t}\right)^{\frac{\epsilon-1}{\epsilon}} + \rho_m^{\frac{1}{\epsilon}} \left(c^i_{m,t}\right)^{\frac{\epsilon-1}{\epsilon}} + \rho_n^{\frac{1}{\epsilon}} \left(c^i_{n,t}\right)^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}} \qquad \text{for } i = \mathfrak{s}, \mathfrak{h} \tag{14}$$

[4] $P^*_{e,t} = P^{sales}_{e,t} - P^{buy}_{e,t} * (1 + loss_factor)/(1 - \gamma)$

where ρ_x, ρ_m and ρ_n are CES distribution parameters and ϵ is the intratemporal elasticity of substitution. In addition $\rho_n = 1 - \rho_x - \rho_m$.

From the consumption basket it is possible to derive the price of the basket:

$$P_t = \left[\rho_x P_{x,t}^{1-\epsilon} + \rho_m P_{m,t}^{1-\epsilon} + \rho_n P_{n,t}^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}. \tag{15}$$

The demand functions for each good and for each consumer:

$$c_{j,t}^{i} = \rho_j \left(\frac{P_{j,t}}{P_t}\right)^{-\epsilon} c_t^i \qquad \text{for} \quad j = x, m, n \quad \text{and} \quad i = \mathfrak{s}, \mathfrak{h}.$$

B.1. Savers

Savers have access to the asset market. They can use their savings to accumulate private capital, that depreciates at the rate δ_k, with investments i_x and i_n. They can also access financial markets, by buying either domestic bonds b (which do not trade on international markets) at a real interest rate r, or by issuing foreign debt b^* at an exogenous real interest rate r^*. Moreover they pay μz^e user fees charged for infrastructure services according. They solve the following intertemporal maximization problem:

$$\max \sum_{t=0}^{\infty} \beta^t \frac{(c_t^{\mathfrak{s}})^{1-1/\tau}}{1-1/\tau},$$

subject to

$$\begin{aligned} P_t b_t^{\mathfrak{s}} - b_t^{\mathfrak{s}*} \;=\; & r_{x,t} k_{x,t-1}^{\mathfrak{s}} + r_{n,t} k_{n,t-1}^{\mathfrak{s}} + w_t L_t^{\mathfrak{s}} + \frac{\mathcal{R}_t}{1+a} + \frac{\mathcal{T}_t}{1+a} - \frac{1+r_{t-1}^*}{1+g} b_{t-1}^{\mathfrak{s}*} + \frac{1+r_{t-1}}{1+g} P_t b_{t-1}^{\mathfrak{s}} \\ & - P_{k,t}\left(i_{x,t}^{\mathfrak{s}} + i_{n,t}^{\mathfrak{s}} + AC_{x,t}^{\mathfrak{s}} + AC_{n,t}^{\mathfrak{s}}\right) - P_t c_t^{\mathfrak{s}}(1+h_t) - \mu z_{t-1}^e - \mathcal{P}_t^{\mathfrak{s}} - \Phi_t^{\mathfrak{s}}, \end{aligned} \tag{16}$$

$$(1+g) k_{x,t}^{\mathfrak{s}} = i_{x,t}^{\mathfrak{s}} + (1-\delta_k) k_{x,t-1}^{\mathfrak{s}}, \tag{17}$$

and

$$(1+g) k_{n,t}^{\mathfrak{s}} = i_{n,t}^{\mathfrak{s}} + (1-\delta_k) k_{n,t-1}^{\mathfrak{s}}, \tag{18}$$

In this problem $\beta = 1/[(1+\varrho)(1+g)^{(1-\tau)/\tau}]$ is the discount factor; ϱ is the pure time preference rate; τ is the intertemporal elasticity of substitution; δ_k is the depreciation rate of private capital; $\mathcal{R}$ are remittances; $\mathcal{T}$ are (net) transfers; h denotes the consumption tax; and $\Phi^{\mathfrak{s}}$ are profits from domestic firms.

Remittances and transfers are divided by $1+a$ as they are partitioned proportionally to the savers' share in aggregate employment. The trend growth rate appears as some variables are dated at $t-1$ and not at t. The capital stocks are de-trended differently from other stock variables. $K^{\mathfrak{s}}_{j,t-1}$ represents the capital stock (before detrending) which was chosen in $t-1$ but is used in t. Therefore, we define $k^{\mathfrak{s}}_{j,t-1} \equiv K^{\mathfrak{s}}_{j,t-1}/(1+g)^t$. Notice that this convention ensures a long run growth rate og g of the capital stock, as $\bar{i}^{\mathfrak{s}}_j = (\delta_k+g)\bar{k}^{\mathfrak{s}}_j$. P_t multiplies both $b^{\mathfrak{s}}_t$ and $b^{\mathfrak{s}}_{t-1}$ because domestic bonds are not indexed to the foreign price level, the numeraire, but to the domestic one. Private capitals does not adjust costlessly, but they incur adjustment costs of the form: $AC^{\mathfrak{s}}_{j,t} \equiv \frac{v}{2}\left(\frac{i^{\mathfrak{s}}_{j,t}}{k^{\mathfrak{s}}_{j,t-1}} - \delta_k - g\right)^2 k^{\mathfrak{s}}_{j,t-1}$, for $j = x, n$ and with $v > 0$. Also foreign liabilities face portfolio adjustment costs: $\mathcal{P}^{\mathfrak{s}}_t \equiv \frac{\eta}{2}(b^{\mathfrak{s}*}_t - \bar{b}^{\mathfrak{s}*})^2$, where $\bar{b}^*$ is the (initial) steady-state value of the private foreign liabilities.

The solution of the savers' maximization problem yields the following conditions.

$$c^{\mathfrak{s}}_t = c^{\mathfrak{s}}_{t+1}\left(\beta\frac{1+r_t}{1+g}\frac{1+h_t}{1+h_{t+1}}\right)^{-\tau}, \tag{19}$$

$$(1+r_t)\frac{P_{t+1}}{P_t} = \frac{1+r^*_t}{\left[1-\eta(b^{\mathfrak{s}*}_t - \bar{b}^{\mathfrak{s}*})\right]}, \tag{20}$$

$$\frac{r_{x,t+1}}{P_{k,t+1}} + 1 - \delta_k + v\Upsilon^{\mathfrak{s}}_{x,t+1}\left(\frac{i^{\mathfrak{s}}_{x,t+1}}{k^{\mathfrak{s}}_{x,t}} + 1 - \delta_k\right) - \frac{v}{2}\left(\Upsilon^{\mathfrak{s}}_{x,t+1}\right)^2 = (1+r_t)\frac{P_{t+1}}{P_t}\frac{P_{k,t}}{P_{k,t+1}}\left(1+v\Upsilon^{\mathfrak{s}}_{x,t}\right), \tag{21}$$

and

$$\frac{r_{n,t+1}}{P_{k,t+1}} + 1 - \delta_k + v\Upsilon^{\mathfrak{s}}_{n,t+1}\left(\frac{i^{\mathfrak{s}}_{n,t+1}}{k^{\mathfrak{s}}_{n,t}} + 1 - \delta_k\right) - \frac{v}{2}\left(\Upsilon^{\mathfrak{s}}_{n,t+1}\right)^2 = (1+r_t)\frac{P_{t+1}}{P_t}\frac{P_{k,t}}{P_{k,t+1}}\left(1+v\Upsilon^{\mathfrak{s}}_{n,t}\right), \tag{22}$$

where $\Upsilon^{\mathfrak{s}}_{j,t} = \left(\frac{i^{\mathfrak{s}}_{j,t}}{k^{\mathfrak{s}}_{j,t-1}} - \delta_k - g\right)$ for $j = x, n$. Equation (19) is the Euler equation, where the consumption path is a function of the real interest rate adjusted for trend growth and of the changes in the consumption tax. Equations (21) and (22) are non-arbitrage conditions which equate the net return of capital in each sector to the real interest rate. Equation (20) is also a non-arbitrage condition with respect to choices in domestic and foreign bonds. The presence of portfolio costs allows to ensure stationarity of non-foreign assets as discussed by Schmitt-Grohé and Uribe (2003). Moreover, this equation implicitly defines a private demand for foreign debt, which explicitly becomes:

$$\eta(b^{\mathfrak{s}*}_t - \bar{b}^{\mathfrak{s}*}) = 1 - \frac{1+r^*_t}{(1+r_t)\frac{P_{t+1}}{P_t}}.$$

where η is the parameter determining the degree of capital mobility. A lower η implies more elastic capital flows, which would keep the domestic rate close to the foreign rate.

We assume that private agents, issuing foreign debt, are charged a premium $\mathfrak{u}$ over the interest rate on commercial debt r_{dc} issued by the government:

$$r^*_t = r_{dc,t} + \mathfrak{u}.$$

B.2. Non-savers

Non-savers cannot access assets, which simplifies calculations of their utility maximization problem. They feature the same utility function as that of savers. On the other hand, they use their income from wages, remittances, and transfers entirely for consumption.
The non-saver's budget constraint:

$$(1+h_t)P_t c_t^{\mathfrak{h}} = w_t L^{\mathfrak{h}} + \frac{a}{1+a}(\mathcal{R}_t + \mathcal{T}_t). \tag{23}$$

These hand-to-mouth consumers are present in most economies, but are particularly relevant for LICs as many households do not have access to financial markets. Moreover, their presence in the model is key to break the Ricardian equivalence.

We aggregate across both types of households, so $x_t = x_t^{\mathfrak{s}} + x_t^{\mathfrak{h}}$ for $x_t = c_t$, $c_{l,t}$, L_t, b_t^*, b_t, $i_{j,t}$, $k_{j,t}$, $AC_{j,t}$, $\mathcal{P}_t$, Φ_t, and the subindices $l = x, n, m$ and $j = x, n$. Bear in mind that $b_t^{\mathfrak{h}*} = b_t^{\mathfrak{h}} = i_{j,t}^{\mathfrak{h}} = k_{j,t}^{\mathfrak{h}} = AC_{j,t}^{\mathfrak{h}} = \mathcal{P}_t^{\mathfrak{h}} = \Phi_t^{\mathfrak{h}} = 0$ for $j = x, n$.

C. The Government

C.1. Public Investment and Efficiency in Infrastructure and Power Plants

The government is responsible for investments in infrastructure $\tilde{z}$ and power plants $\tilde{k}_e$. Infrastructure is a public good (does not enter the maximization problem of the single firm) and can only be consumed domestically, whereas electricity, produced by power plants, is a private good sold to the domestic firms and exported to South African costumers.
The gross investment in infrastructure is defined by: $P_{z,t}\mathbb{I}_{z,t}$ and in power stations by: $P_{ke,t}\mathbb{I}_{ke,t}$.
For modeling the construction cost overruns, we propose a slight modification of the approach with absorptive capacity constraints in Buffie et al. (2012) to incorporate the existence of two public investment categories:

$$\mathbb{I}_{z,t} = \mathcal{H}_t(i_{z,t} - \bar{\imath}_z) + \bar{\imath}_z \tag{24}$$

$$\mathbb{I}_{ke,t} = \mathcal{H}_t(i_{ke,t} - \bar{\imath}_{ke}) + \bar{\imath}_{ke} \tag{25}$$

The risk of large cost overruns is commonly associated with large and complex projects. This risk is particularly high in low-income countries, which face capacity constraints, including poor planning and coordination, weak oversight, and other implementation issues. To capture this phenomenon in

the model, we multiply new investment in either sector $(i_{z,t} - \bar{\imath}_z)$ and $(i_{ke,t} - \bar{\imath}_{ke})$ by $\mathcal{H}_t$.

$$\mathcal{H}_t = \left(1 + \frac{i_{z,t}}{z_{t-1}} + \frac{i_{ke,t}}{k_{e,t-1}} - (\delta_z + g) - (\delta_{ke} + g)\right)^{\phi} \tag{26}$$

where $\phi \geq 0$ is the parameter governing the severity of the project implementation capacity constraint in the public sector. The constraint is applicable to both type of public investments. However it affects only implementation costs for new projects: in a steady state, $\left(1 + \frac{\bar{\imath}_z}{\bar{z}} + \frac{\bar{\imath}_{ke}}{\bar{k}_e} - (\delta_z + g) - (\delta_{ke} + g)\right)^{\phi} = 1$ as $\bar{\imath}_z = (\delta_z + g)\bar{z}$ and $\bar{\imath}_{ke} = (\delta_{ke} + g)\bar{k_e}$.

We allow for further inefficiencies in public physical capital creation. Public investments in infrastructure i_z and in power plants i_{ke} produce additional infrastructure z and power plants k_e according to:

$$(1 + g)z_t = (1 - \delta_z)z_{t-1} + i_{z,t}, \tag{27}$$

$$(1 + g)k_{e,t} = (1 - \delta_{ke})k_{e,t-1} + i_{ke,t}, \tag{28}$$

but some of the newly built public capital might not be economically valuable, since *effectively productive* infrastructure $\tilde{z}_t$, and *effectively productive* power plants $\tilde{k}_{e,t}$ which are actually used in technologies (1), (2), and (9) evolve according to:

$$\tilde{z_t} = \bar{s}_z\bar{z} + s_z(z_t - \bar{z}), \quad \text{with} \quad \bar{s}_z \in [0, 1] \quad \text{and} \quad s_z \in [0, 1], \tag{29}$$

$$\tilde{k}_{e,t} = \bar{s}_{ke}\bar{k_e} + s_{ke}(k_{e,t} - \bar{k_e}), \quad \text{with} \quad \bar{s}_{ke} \in [0, 1] \quad \text{and} \quad s_{ke} \in [0, 1], \tag{30}$$

where $\bar{s}_j$ and s_j $(j = z, ke)$ are parameters of efficiency at and off steady state, $\bar{z}$ is infrastructure at the (initial) steady state, and $\bar{k_e}$ are power plants at the (initial) steady state.

Note that by combining equations (27) with (29), and (28) with (30), we obtain

$$(1 + g)\tilde{z}_t = (1 - \delta_z)\tilde{z}_{t-1} + s_z(i_{z,t} - \bar{\imath}_z) + \bar{s}_z\bar{\imath}_z, \tag{31}$$

$$(1 + g)\tilde{k}_{e,t} = (1 - \delta_{ke})\tilde{k}_{e,t-1} + s_{ke}(i_{ke,t} - \bar{\imath}_{ke}) + \bar{s}_{ke}\bar{\imath}_{ke}, \tag{32}$$

where $\bar{\imath}_z = (\delta_z + g)\bar{z}$ is the public investment in infrastructure at the (initial) steady state and $\bar{\imath}_{ke} = (\delta_{ke} + g)\bar{k}_e$ is the public investment in infrastructure at the (initial) steady state. Since $s_j \in [0, 1]$, $(j = z, ke)$ this specification makes clear that *one* dollar of additional public investment either in infrastructure $(i_{z,t} - \bar{\imath}_z)$ or in power plants $(i_{ke,t} - \bar{\imath}_{ke})$ does not translate into *one* dollar of effectively productive capital ($\tilde{z}_t$ or $\tilde{k}_{e,t}$). A similar specification for public investments inefficiencies can be found in Berg et al. (2010) and Agénor (2010).

C.2. Government Budget Constraint

In addition to public investment, the government provides transfers to public and services the debt. It receives revenues from the consumption tax, user fees for infrastructure services, which are expressed as a fixed multiple/fraction f of recurrent costs, that is $\mu = f\delta_z P_{zo}$, and the electricity sales (domestic and exports).

The government has three instruments to finance its deficit: domestic borrowing $\Delta b_t = b_t - b_{t-1}$, external concessional borrowing $\Delta d_t = d_t - d_{t-1}$, or external commercial borrowing $\Delta d_{c,t} = d_{c,t} - d_{c,t-1}$. The resulting budget constraint:

$$\begin{aligned} P_t\Delta b_t + \Delta d_{c,t} + \Delta d_t = \frac{r_{t-1}-g}{1+g}P_t b_{t-1} + \frac{r_{d,t-1}-g}{1+g}d_{t-1} + \frac{r_{dc,t-1}-g}{1+g}d_{c,t-1} \\ + P_{z,t}\mathbb{I}_{z,t} + P_{ke,t}\mathbb{I}_{ke,t} + \mathcal{T}_t - h_t P_t c_t - \mathcal{G}_t - \mathcal{N}_t - \mu\tilde{z}_{t-1} - P_{e,t}q_t^{domestic} - P^*_{E,t}q_{e,t}^{Foreign}, \end{aligned} \tag{33}$$

where d, dc, $\mathcal{G}$, $\mathcal{N}$, $P_z\mathbb{I}_z$, $P_{ke}\mathbb{I}_{ke}$, $P_{e,t}q_t^{domestic}$, and $P^*_{E,t}q_{e,t}^{Foreign}$ denote concessional debt, external commercial debt, grants, SACU revenues[5], gross public investment on infrastructure, gross public investment on power plants, receipts from selling of energy domestically and abroad, respectively. r_d and r_{dc} are the real interest rates (in dollars) on concessional and commercial loans. The two interest rates behave in different ways, the interest rate on concessional loans is exogenous and is set to be constant $r_{d,t} = r_d$,, while the interest rate on external commercial debt is endogenous as it incorporates a risk premium that depends on the deviations of the external public debt to GDP ratio $\left(\frac{d_t + d_{c,t}}{y_t}\right)$ from its (initial) steady-state value $\left(\frac{\bar{d}+\bar{d}_c}{\bar{y}}\right)$. That is:

$$r_{dc,t} = r^f + \upsilon_g e^{\eta_g\left(\frac{d_t+d_{c,t}}{y_t} - \frac{\bar{d}+\bar{d}_c}{\bar{y}}\right)}, \tag{34}$$

where r^f is a risk-free world interest rate. However we set $\upsilon_g > 0$ and $\eta_g = 0$, therefore this specification implies an exogenous risk premium that does not depend on public debt.

C.3. Fiscal Adjustments

We set the path for borrowing and amortization of concessional loans provided by official creditors as exogenous. This is the case as the lending terms are more favorable than other loans and therefore are chosen as a first resort. To quantify the size of the required policy action (financing or fiscal adjustment) given the paths for public investment and concessional borrowing, we define the fiscal gap *before* policy adjustment ($\mathfrak{Gap}_t$):

$$\begin{aligned} \mathfrak{Gap}_t = \frac{1+r_d}{1+g}d_{t-1} - d_t + \frac{r_{dc,t-1}-g}{1+g}dc_{t-1} + \frac{r_{t-1}-g}{1+g}P_t b_{t-1} \\ + P_{z,t}\mathbb{I}_{z,t} + P_{ke,t}\mathbb{I}_{ke,t} + \mathcal{T}_o - h_o P_t c_t - \mathcal{G}_t - \mathcal{N}_t - \mu z^e_{t-1} - P_{e,t}q_t^{domestic} - P^*_{E,t}q_{e,t}^{Foreign}. \end{aligned} \tag{35}$$

[5]The Southern African Customs Union (SACU) is a customs union between Lesotho, South Africa, Botswana, Namibia, and Swaziland. The revenues that arise from it are a substantial part of Lesotho budget, and given the small size of Lesotho compared to the custom union, they behave exogenously with respect to domestic developments.

This expression implies that $\mathfrak{Gap}_t$ corresponds to expenditures (including interest rate payments on debt) less revenues and concessional borrowing, when transfers and taxes are kept at their *initial* levels $\mathcal{T}_o$ and h_o, respectively. Using this definition, we can rewrite the budget constraint (33), in any given year, as:

$$\mathfrak{Gap}_t = P_t \Delta b_t + \Delta d_{c,t} + (h_t - h_o) P_t c_t - (\mathcal{T}_t - \mathcal{T}_o). \tag{36}$$

In the transition path, the $\mathfrak{Gap}_t$ in (36) can be covered by borrowing, either domestic and/or external commercial: $P_t \Delta b_t + \Delta d_{c,t}$, or by a fiscal adjustment which can take the form of a variation in taxes $(h_t - h_o) P_t c_t$, and/or of transfers $-(\mathcal{T}_t - \mathcal{T}_o)$. In Lesotho's case we are going to focus on external commercial borrowing only.

On the other hand, in the long run the consumption tax and transfers eventually adjust to cover the entire gap (i.e., $P_t \Delta b_t + \Delta d_{c,t} \xrightarrow{t \to \infty} 0$) in order to ensure debt sustainability. Policy makers divide the burden of adjustment (net windfall when $\mathfrak{Gap}_t < 0$) between transfers cuts and tax increases. We define the level of taxes and transfers which would allow to stabilize the endogenous debt level, this will play a role in the reaction function of these variables:

$$h_t^{\text{target}} = h_o + (1 - \lambda) \frac{\mathfrak{Gap}_t}{P_t c_t} \tag{37}$$

and

$$\mathcal{T}_t^{\text{target}} = \mathcal{T}_o - \lambda \mathfrak{Gap}_t, \tag{38}$$

These expressions take into account the fact that fiscal adjustment can be split between the two fiscal instruments, taxes and transfers. This is done according to the policy parameter $\lambda (\in [0, 1])$. When $\lambda = 0$ ($\lambda = 1$) all the adjustment falls on taxes (transfers).

The reaction functions for taxes and transfers are:

$$h_t = Min \left\{ h_t^r, h_t^u \right\} \tag{39}$$

and

$$\mathcal{T}_t = Max \left\{ \mathcal{T}_t^r, \mathcal{T}_t^l \right\}, \tag{40}$$

where h_t^u is a possibly time-varying ceiling on taxes, $\mathcal{T}_t^l$ is a possibly time-varying floor for transfers[6], and h_t^r and $\mathcal{T}_t^r$ are determined by the fiscal rules:

$$h_t^r = h_{t-1} + \lambda_1 (h_t^{\text{target}} - h_{t-1}) + \lambda_2 \frac{(x_{t-1} - x^{\text{target}})}{y_t} \tag{41}$$

[6]The fact they are time-varying allows us to model staggered tax and transfers structures.

and

$$\mathcal{T}_t^r = \mathcal{T}_{t-1} + \lambda_3(\mathcal{T}_t^{\text{target}} - \mathcal{T}_{t-1}) - \lambda_4(x_{t-1} - x^{\text{target}}) \tag{42}$$

and

$$\lambda_1, \lambda_2, \lambda_3, \lambda_4 > 0, \quad \lambda_1 = \begin{cases} \lambda_{1a} & \text{if } x_{t-1} \geq x^{\text{target}} \\ \lambda_{1b} & \text{if } x_{t-1} < x^{\text{target}} \end{cases}, \quad \lambda_3 = \begin{cases} \lambda_{3a} & \text{if } x_{t-1} \geq x^{\text{target}} \\ \lambda_{3b} & \text{if } x_{t-1} < x^{\text{target}} \end{cases} \tag{43}$$

with y defined in (10) and x being one of the two types of endogenous debt (b or d_c) depending on whether the rules respond to domestic debt or commercial debt. The target for debt x^{target} is given exogenously. The reaction parameters associated to the distance from the target for taxes and transfers (λ_1 and λ_3 respectively) are allowed to be of different magnitude if the debt target has been met or not; the reason is that once that target has been met the authorities can concentrate relatively more on the fiscal adjustment (if $\lambda_{1a} < \lambda_{1b}$ or $\lambda_{3a} < \lambda_{3b}$).

The specification of the fiscal adjustment presented in this subsection — with its targets, reaction functions, and the budget constraints — encompasses the main trade-offs of fiscal adjustment. Abrupt adjustment is painful, therefore the government tends to smooth tax increases and expenditure cuts ($\lambda_{1a} > 0$ and $\lambda_{3a} > 0$). However this leaves a fiscal gap which has to be covered endogenously by government debt. As long as $h_t < h_t^{\text{target}}$ and $\mathcal{T} > \mathcal{T}_t^{\text{target}}$ debt will increase, when the sign will reverse the resulting fiscal surplus will paid back the accumulated debt. Mechanically debt will decrease as fiscal instruments react to it ($\lambda_2 > 0$ and $\lambda_4 > 0$), however if this reaction is too low, or the bounds on taxes and transfers are too tight the path of public debt could become explosive. This underscores the risks associated with large public investment projects financed by public debt.

D. Market-Clearing Conditions

The labor market has a fixed supply and its competitive structure allows it to clear continuously:

$$L^{\mathfrak{s}} + L^{\mathfrak{h}} = L = L_x + L_n, \tag{44}$$

The domestic electricity market clears:

$$E_{x,t} + E_{n,t} = q_{e,t}^{Domestic} = q_{e,0} + \gamma(q_{e,t} - q_{e,0}) \tag{45}$$

In the non-tradable market, the supply is matched with the total demand, coming from the consumption aggregated across consumers and investments in private capital, infrastructure, and energy capital:

$$q_{n,t} = \rho_n \left(\frac{P_{n,t}}{P_t}\right)^{-\epsilon} c_t + a_k \left(i_{x,t} + i_{n,t} + AC_{x,t} + AC_{n,t}\right) + a_z \mathbb{I}_{z,t} + a_{ke} \mathbb{I}_{ke,t}. \tag{46}$$

The last equation of the model is the national budget constraint. It aggregates across consumers, firms, and government. The resulting identity states that growth in the country's net foreign debt

equals the difference between national spending and national income:

$$\begin{aligned} d_t - d_{t-1} + d_{c,t} - d_{c,t-1} + b_t^* - b_{t-1}^* = & \frac{r_d - g}{1+g} d_{t-1} + \frac{r_{dc,t-1} - g}{1+g} d_{c,t-1} + \frac{r_{t-1}^* - g}{1+g} b_{t-1}^* \\ & + \mathcal{P}_t + P_{z,t}\mathbb{I}_{z,t} + P_{ke,t}\mathbb{I}_{ke,t} + P_{k,t}\left(i_{x,t} + i_{n,t} + AC_{x,t} + AC_{n,t}\right) \\ & + P_t c_t - P_{n,t} q_{n,t} - P_{x,t} q_{x,t} - P_{E,t}^* q_{e,t}^{Foreign} - \mathcal{R}_t - \mathcal{G}_t - \mathcal{N}_t. \end{aligned} \tag{47}$$

Notice that only foreign energy sales enter equation (47) as domestic sales are a production factor for private firms.

III. Calibration

Given the lack of the necessary data for the Lesotho economy, most of the structural parameters are calibrated for an average Sub-Saharan African country. A detailed explanation of the choice of each parameter can be found in Buffie et al. (2012). In this section there is a discussion of the parameters which are either specific to Lesotho or to the electricity sector. As the project is tentatively projected to start in the fiscal year 2020/21, that year is used for the initial conditions as long as it is not otherwise specified.

A. Energy Sector

- β_x and β_n: *Cost share of electricity in the T and NT sectors.* Given that there is little data for LICs on this matter, we use data from EU, USA, China, and Japan gathered by the European Commission (2014). Most of tradables in Lesotho are textiles and diamond mining, therefore we approximate β_x to 0.02, and because NT are generally less energy intensive we approximate β_n to 0.01. In order to verify the robustness of this assumption we present in the appendix a calibration in which we vary these two parameters. Specifically, we decrease both β_x and β_n by 50% in one simulation and we increase them by 50% in another.

- α_{ke}: *Cost share of NT-inputs in the production of power plants.* The choice of 0.5 matches the guesstimate for other capital goods.

- γ: *Share of electricity sold domestically from the Lesotho Highlands Water Project (LHWP-II).* We assume 200 MW of 1200 MW used for Lesotho consumption, which implies a choice of 0.16.

- $\bar{s}_{ke}$: *Efficiency of public investment in power plants, at steady state.* We back out this parameter (0.6) from the existing electricity investment, production quantity, and production technology.

- s_{ke}: *Efficiency of public investment in power plants, dynamic off-steady state.* This parameter is calibrated at 0.4 to be close to a similar project in South Africa, the Ingula pump storage scheme. Costs shot up from the feasibility study estimate of R8.9 billion up to a currently estimated R26 billion as West (2012), Slabbert (2015), and Webb (2015) report. The calibration of 0.4 is a midpoint between the Ingula project and the predictions by Ansar et al. (2014),

who show that on average large dams have cost overruns of 96% and even higher for non-North American projects[7].

- $\frac{i_{ke,o}}{y_o}$: *Initial ratio of energy related investment to GDP.* 1.3% of GDP, from LEC (2011).
- δ_{ke}: *Depreciation rate for energy related capital.* Dams present a lower depreciation rate than the average capital present in an economy. Therefore we set it to 0.04, close to LHDA estimates.
- $q_{e,o}$: *Initial production of electricity.* Currently Lesotho imports part of the electricity it consumes from South Africa and Mozambique. The paper assumes that even once production from the new project starts these imports will continue as Lesotho is facing electricity shortages and needs more electricity to sustain its development. This reason, coupled with the linearity of the production function for electricity pushes to use the current consumption value rather than the production one. Specifically, the papers employs the value of 707 million kWh, which comes from the CIA World Factbook for 2012. With this parameter and the initial investment in energy it is possible to back out the production parameter for the existing energy from (9) and (32): $a_{e,0} = q_{e,o}\left(\bar{s}_{ke}\frac{i_{ke,0}}{P_{ke,0}*(\delta_{ke}+g)}\right)^{-1} = 99.7051$
- a_e: *Production parameter for new energy.* This parameter is calibrated at 847.11 to allow the new effective energy capital to be equivalent to 1200 MW at the new steady state, in order to be able to use engineering concepts such as the capacity factor of the power plant.
- $loss_factor$: *Loss factor for new production technology.* To produce 1 kWh with the proposed pump storage scheme, there are going to be necessary 1.5 kWh of electricity, which amount to a 50% loss factor.
- θ: *Capacity Factor.* The rate at which a power plant is used determines its capacity factor, which is defined as: $\frac{\text{total yearly production in MWh}}{1200MW*365*24h}$. The value of 32% is close to the plant being used during all hours of the week in which there is an off-peak rate in the ESKOM tariff scheme to pump water up and then discharging 33% less given the loss factor. This value is going to be used as a baseline in case Lesotho's foreign partners agree to purchase electricity both during high and medium demand. To define these values we use information from ESKOM's Megaflex rate: high demand matches peak hours, medium demand matches standard hours as shown in figure 1. We employ this choice because ESKOM is the most likely partner in the project, given the geographical position of Lesotho and the size of the South African electricity market. The alternative value for θ is 9% in case negotiations lead to a low demand scenario. This value may seem too small but many pump storage scheme face similar capacity factors. Some examples can be found in Planete-TP (2008) and Hydrelect (2012).
- $P_{e,0}^{buy}$: *Initial price of energy purchases from abroad.* This price (0.0012833) comes from the MEGAFLEX off-peak tariff scheme of ESKOM for fiscal year 2015/16. It is expressed in units of 2015/16 Lesotho GDP per million of kWh. It takes into account the fact that for 3 months per year there is a high demand season and for the remaining 9 a low demand one. The underlying assumption is that the plant is going to be used at the same rate in both seasons.

[7]Castellano et al. (2015) suggest that cost overruns are much smaller at 33% however they have a much smaller dataset with only 5 dams.

$\frac{9/12*P_e^{buy,low\ \ season}+3/12*P_e^{buy,high\ \ season}}{PY} = \frac{0.75*0.32+0.25*0.37}{25909*100} = 0.0012833.$
Another assumption embedded with this specification is that buy and sell prices are going to stay constant as a share of GDP. In recent years there has been an erratic behavior of ESKOM prices, with political constraints to keep them low (and therefore to increase less than GDP) and to increase them to face shortages and disruptions (and therefore to increase more than GDP). As our simulations start in FY 2020/21, we take an agnostic position by assuming the same growth rate.

- $P_{e,0}^{sell}$: *Initial price of energy sales abroad.* This price is computed similarly to the price for purchases. In addition to the two seasons scheme, it is necessary to consider whether the sales are made all at the peak rate or if some are made at the standard rate. If the outcome is one of low overall demand then all the sales are going to be made at the peak rate. In this case the price is: $\frac{9/12*P_e^{sell,low\ \ season,peak}+3/12*P_e^{sell,high\ \ season,peak}}{PY} = \frac{0.75*0.8+0.25*2.4}{25909*100} = 0.004631.$ The case of higher demand is found by assuming that Lesotho is going to purchase electricity during all off-peak hours, i.e. for 81 hours per week. Given that there is a 50% loss factor the plant is going to be able to sell only for 54 hours per week, which implies a 32% capacity factor. After selling at the peak tariff for the 25 hours, the remaining 29 are sold at the standard rate. This translates into the following price:
$\frac{\frac{9}{12}*(\frac{25}{54}*P_e^{sell,low\ \ season,peak}+\frac{29}{54}*P_e^{sell,low\ \ season,standard})+\frac{3}{12}*(\frac{25}{54}*P_e^{sell,high\ \ season,peak}+\frac{29}{54}*P_e^{sell,high\ \ season,standard})}{PY} =$
$\frac{0.75*(25/54*0.8+29/54*0.56)+0.25*(25/54*2.4+29/54*0.74)}{25909*100} = 0.0033983.$

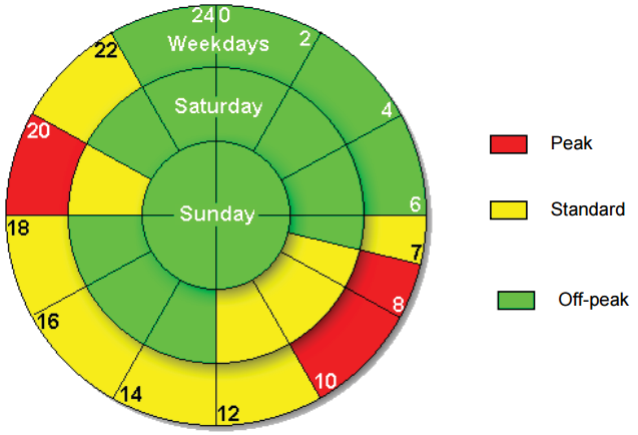


Figure 1: Megaflex Tariff Structure from ESKOM (2014)

B. Lesotho Specific

- r_0: *The initial interest rate for public domestic debt.* 0.05 is the IMF staff estimate for FY 2020/21.
- $r_{dc,0}$: *The initial interest rate for public external debt.* 0.06 is the IMF staff estimate for FY 2020/21.
- h_0: *The initial consumption tax rate.* 0.14 is the IMF staff estimate for FY 2020/21.

- b_0^*: *Initial private external debt to GDP*. 0% is the IMF staff estimate for FY 2020/21.
- b_0: *Initial public domestic debt to GDP*. 4.2% is the IMF staff estimate for FY 2020/21.
- $d_{c,0}$: *Initial public external commercial debt to GDP*. 13.5% is the IMF staff estimate for FY 2020/21.
- d_0: *Initial public concessional debt to GDP*. 29.5% is the IMF staff estimate for FY 2020/21.
- $\mathcal{G}_0$: *Initial grants to GDP*. 3% is the IMF staff estimate for FY 2020/21.
- $\mathcal{N}_0$: *Initial SACU revenues to GDP*. 18.2% is the IMF staff estimate for FY 2020/21.
- $\mathcal{R}_0$: *Initial remittances to GDP*. 9% is the IMF staff estimate for FY 2020/21.
- $\frac{i_{ke,o}}{y_o}$: *Initial ratio of non-energy related public investment to GDP* 18%
- *imp2gdp*: *Imports to GDP*. The value of 98% is then used to compute the share parameters in the CES aggregator.
- $\delta_x = \delta_n = \delta_k$: *Depreciation rate for traded, non-traded, and infrastructural sectors*. There is a paucity of data on depreciation rates for LICs, therefore we employ the advanced economies estimates of 0.05.
- $\lambda_{1a} = \lambda_{3a}$: *Fiscal reaction parameter (policy instrument terms) when debt is higher than its target*. This is calibrated to be the main policy instruction term as it is most relevant when the government is scaling up investments. The value of 0.25 allows for a smooth fiscal adjustment and implies that, *ceteris paribus*, for each unit of distance from the target the government is going to raise taxes (or lower transfers) by 0.25 units.
- $\lambda_{1b} = \lambda_{3b}$: *Fiscal reaction parameter (policy instrument terms) when debt is lower than its target*. Once the government has reached its objective for debt it can focus entirely on adjusting taxes, so this parameter is calibrated to 0.99.
- $\lambda_2 = \lambda_4$: *Fiscal reaction parameter (debt instrument terms)*. The value of 0.02 allows a smooth transition to the target level of debt.

Parameter	Value	Definition
τ	0.34	Intertemporal elasticity of substitution
ϵ	0.50	Intratemporal elasticity of substitution across goods
α_x	0.40	Capital's share in value added in the traded sector
α_n	0.55	Capital's share in value added in the non-traded sector
β_x	0.02	Energy's share in value added in the traded sector
β_n	0.01	Energy's share in value added in the non-traded sector
ξ_x, ξ_n	0.00	Capital learning externalities
σ_x, σ_n	0.00	Sectoral output learning externalities
$\alpha_k, \alpha_z, \alpha_{ke}$	0.50	Cost share of non-traded inputs in the production of capital
ψ_x, ψ_n	0.17	Elasticities of sectoral output with respect to infrastructure
$imp2gdp$	0.98	Imports to GDP
VA_n	0.49	Value added in NT-sector
$\delta_x, \delta_n, \delta_z$	0.05	Depreciation rate for traded, non-traded, and infrastructural sector
δ_{ke}	0.04	Depreciation rate for energy sector
v	7.69	Capital adjustment cost parameter
μ	0.05	User fees parameter for infrastructure services
g	0.015	Trend growth rate
a_e	847.1	Production parameter for new energy
$a_{e,0}$	99.7	Production parameter for existing energy
$q_{e,0}^{Foreign}$	0	Initial energy sales abroad
$q_{e,0}^{Domestic}$	707	Initial energy sales domestically
γ	0.16	Share of new domestic energy sales
$loss_factor$	0.5	Loss factor for new production technology
θ	0.32	Capacity factor for the new plant
$P_{e,0}^{sell}$	0.0034	Initial price energy sales abroad
$P_{e,0}^{buy}$	0.0013	Initial price energy purchases from abroad
r_o	0.05	Initial real interest rate on domestic debt
r_o^*	0.05	Initial real interest rate on private external debt
r^f	0.04	Real risk-free foreign interest rate
r_d	0.00	Real interest rate on concessional loans
$r_{dc,o}$	0.06	Initial real interest rate on public commercial loans
η	1.00	The portfolio adjustment costs parameter
η_g	0.00	Public debt risk premium parameter
R_o	0.3	Initial return on infrastructure
b_o	0.042	Initial public domestic debt to GDP ratio
d_o	0.295	Initial public concessional debt to GDP ratio
$d_{c,o}$	0.135	Initial public external commercial debt to GDP ratio
b_o^*	0.00	Initial private external debt to GDP ratio
$\mathcal{G}_o$	0.03	Grants to GDP ratio
$\mathcal{R}_o$	0.09	Remittances to GDP ratio
$\mathcal{N}_o$	0.185	SACU Revenues to GDP ratio

Parameter	Value	Definition
$i_{z,o}$	0.18	Initial ratio of infrastructure investment to GDP
$i_{ke,o}$	0.013	Initial ratio of energy investment to GDP
$\bar{s}_z, s_z$	0.60	Efficiency of public investment in infrastructure
$\bar{s}_{ke}$	0.60	Efficiency of steady state public investment in energy
s_{ke}	0.50	Efficiency of new public investment in energy
ϕ	0.00	Absorptive capacity parameter
h_o	0.14	Initial consumption tax
$\mathcal{T}_o$	0.18	Initial transfers to GDP ratio
λ	0.00	Division of fiscal adjustment parameter
$\lambda_{1a}, \lambda_{3a}$	0.25	Fiscal reaction parameters (policy instrument terms) when debt is higher than its target
$\lambda_{1b}, \lambda_{3b}$	0.99	Fiscal reaction parameters (policy instrument terms) when debt is lower than its target
λ_2, λ_4	0.02	Fiscal reaction parameters (debt terms)
a	1.50	Labor ratio of non-savers to savers

Table 1: Baseline Parameters Calibration

IV. Scenarios

All scenarios assume the same path for public investment in energy capital over the construction and operation periods. This path is exogenous and is determined by the technological aspects of such projects. The path is going to deliver a common amount of public energy capital as a dam is a binary investment, i.e. the government has to build the full dam to be able to operate it. The total investment into the construction of the dam is USD one billion over 7 years with a bell-shaped cost distribution. After that, investment is assumed constant to offset depreciation.

The fiscal implications, focus of this paper, are going to vary in different scenarios according to the efficiency of investment.

For the first 7 years the shock is deflated by the current nominal GDP in order to input data as a function of future nominal GDP. This investment path comes on top of the existing one. $\frac{s_{ke} P_{ke,0} (i_{ke,t} - i_{ke,0})}{GDP_0}$.

1	2	3	4	5	6	7	$8 - \infty$
3.53	5.02	4.75	6.00	4.27	4.04	2.55	1.30

Table 2: Investment in energy path

A. High efficiency and high capacity factor

The first scenario implies a high efficiency of building the dam and a high capacity utilization factor for electricity production.

High efficiency is defined as keeping construction costs within the projected budget, at around USD one billion. In the model, this implies $s_{ke} = 1$: every dollar spent on the dam translates into one dollar of effective capital for producing electricity. In practice, based on cross-country experience, it is unlikely that there will be no cost overruns, nevertheless, it provides a useful baseline scenario.

For prices, at which the electricity is sold to and purchased from external market, we use the current tariff structure in South Africa (as published by ESKOM). The actual prices are subject to negotiations between the two countries. Similarly, the capacity utilization factor, which determines the quantity of electricity produced, will also be established by a production purchasing agreement between the two parties. This scenario assumes a high demand from abroad and, therefore, a high capacity factor. Correspondingly, the per unit price will be lower in this case of high demand rather than in a case in which there is low demand from South Africa; the reason is that with high demand electricity is sold both at peak and standard rate, on the other hand with low demand all electricity is sold at peak rate. It is still beneficial to increase capacity even if marginal sales are done at the lower rate of standard prices as on the margin, net sales are still positive. This makes net benefit from the project increasing monotonically with the capacity factor.

A.1. No financing

As a baseline, to determine domestic costs in terms of higher taxes for the economy, this scenario assumes that no external or domestic financing is available and all the adjustment is done through indirect taxes.

The investment in the energy sector affects the economy through three different channels. The direct one is through the government budget constraint. Initially, the government pays for building the dam by raising domestic revenue (taxes) and later, after the completion of the project, benefits from electricity sales, after covering the costs, which include depreciation of the dam (last panel in figure 2). In the absence of other financing, the government has to raise the tax rate to around 20% in period 3 to generate sufficient funds for construction. Once the construction is over, the tax rate is allowed to decline to below 10% after 9 years and remains at that level to cover other government outlays. This has a first-order effect on consumption, which takes a hit in the construction period, but in the long run it becomes 5% higher than originally. Similarly, private investments are crowded out initially as private savings decline, but in the long run they are higher as overall income (i.e. GDP) is higher.

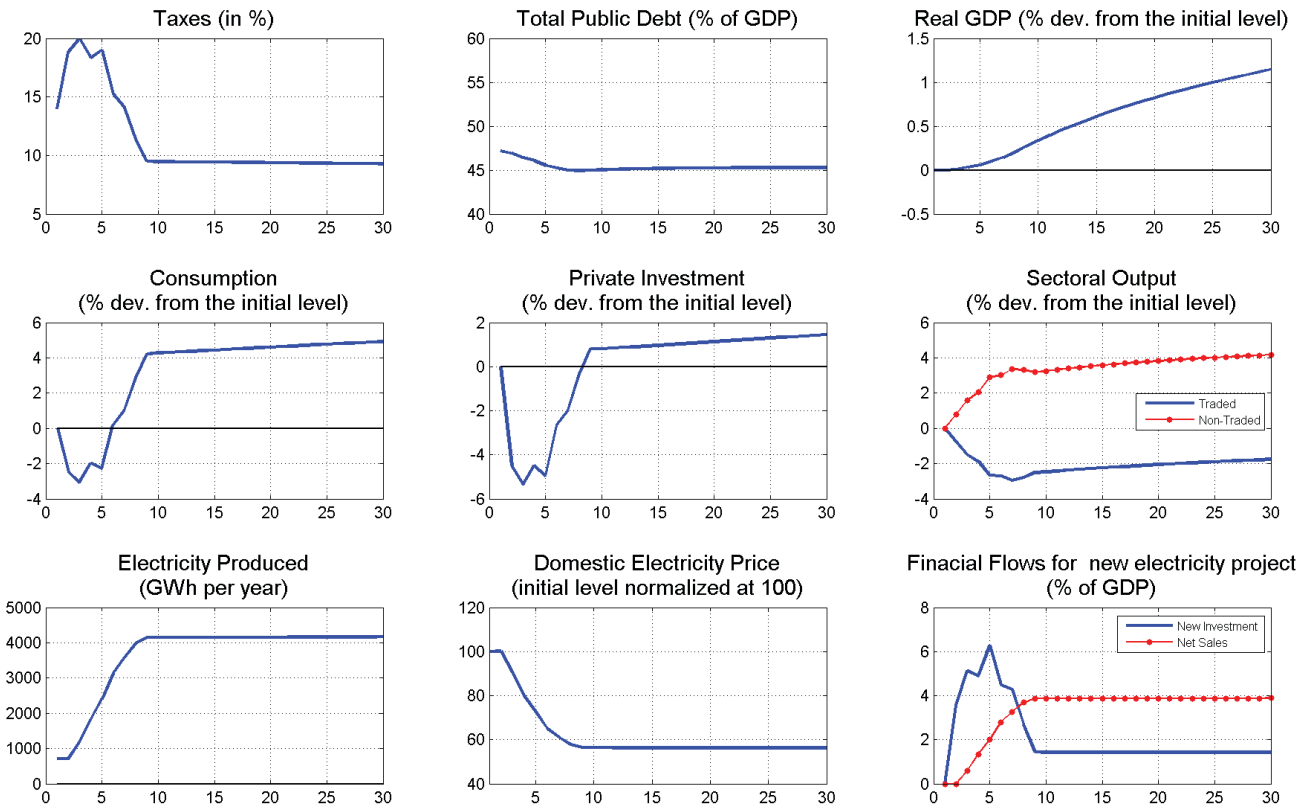


Figure 2: High efficiency, high capacity factor, and no financing available.

The project has indirect effect on the economy through the domestic electricity market, as part of the production is sold domestically. With increased electricity production (seventh panel), the domestic electricity price declines (eight panel). This has an incremental impact on the costs of private investments and production, and in turn on consumption (i.e. wealth effect). This effect is quantitatively smaller than the previous one, as a result of the calibration. The electricity shares in good production are relatively small at $\beta_x = 0.02$ and $\beta_n = 0.01$ respectively.

The dam is built using imported machinery and non-tradable goods. This explains why there is an increase in non-tradables and a less-than-proportional decrease in tradables (sixth panel).

Overall, in this scenario, the project has a positive long-term effect of permanently higher aggregate consumption (by 5%). However, in the transition periods taxes have to increase substantially and this crowds out both consumption and private investments. Therefore, in the next subsection we analyze a case in which commercial financing is available.

A.2. Commercial financing

Access to outside financing of the budget deficit allows the government to smooth the transition period (dam construction), and avoids abrupt changes in tax rates affecting the consumption and investment like in the previous scenario.

In this scenario, the government has access to financing on commercial terms. There is no change in the project assumptions themselves as can be seen in figure 3. The government faces the same construction costs and generates same revenues; the private sector consumes the same amount of electricity and pays the same price.
The results are similar to the previous case. In the long run, effects on economy are close. Consumption and investment stabilize at similar levels, and tax rates are within one percentage point from each other.

The main difference is in the path of tax rates and the level of public debt. Debt increases by 5.5 percentage points of GDP initially before coming back to the no-financing path after the project completion. This allows for smoother consumption path. Taxes do not have to be raised initially as much, but need to be kept higher longer to repay higher debt. This is positive for households as consumption decreases by less than 1% at peak instead of more than 3%. Private investment still experiences crowding out but by a lower degree.

This calibration is very favorable and understandingly yields big positive welfare gains. The project increases long run consumption and debt has to increase only marginally to limit consumption crowding out, as the fiscal adjustment required is relatively small given size and benefits of the project.

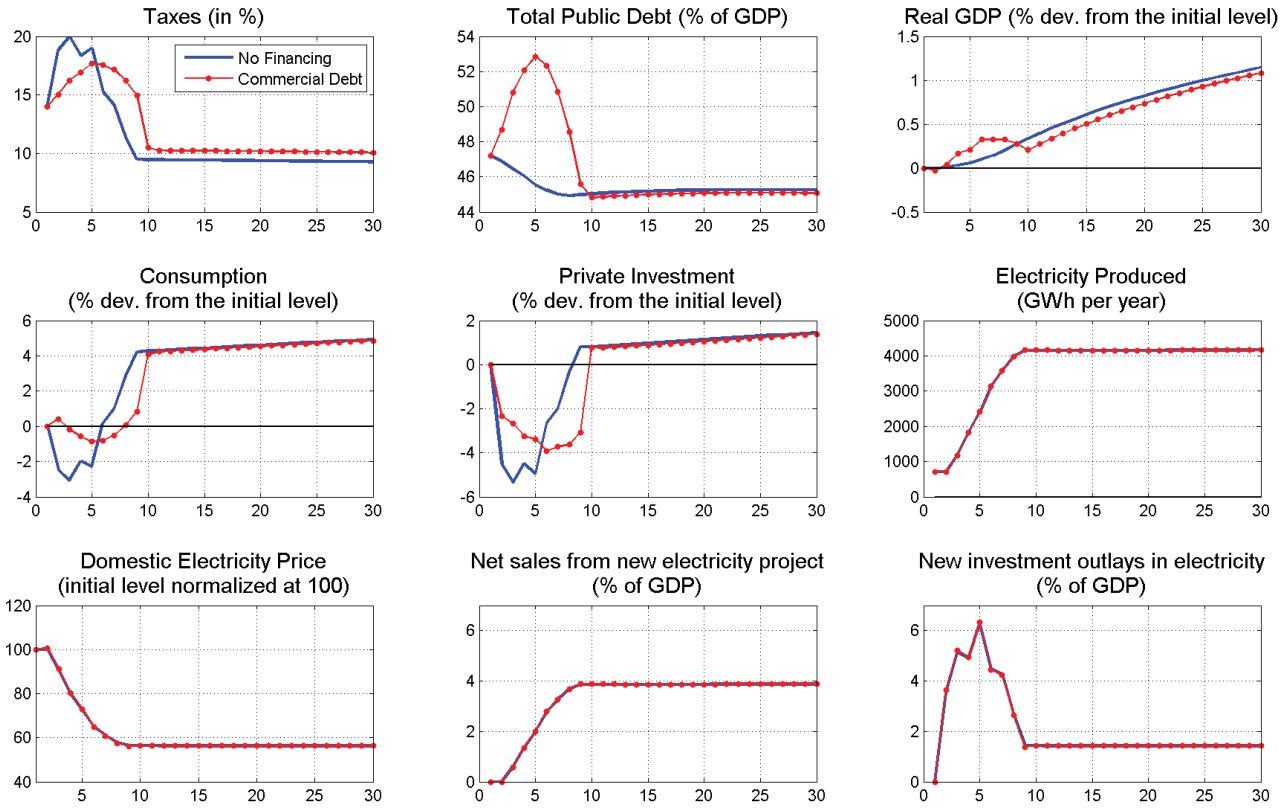


Figure 3: High efficiency and high capacity factor. The impact of commercial financing.

However the underlying assumptions are highly optimistic and might not be realized. In the following scenarios, we look into the impact of allowing for lower efficiency in building the dam and for a lower demand from abroad.

B. Low efficiency and high capacity factor

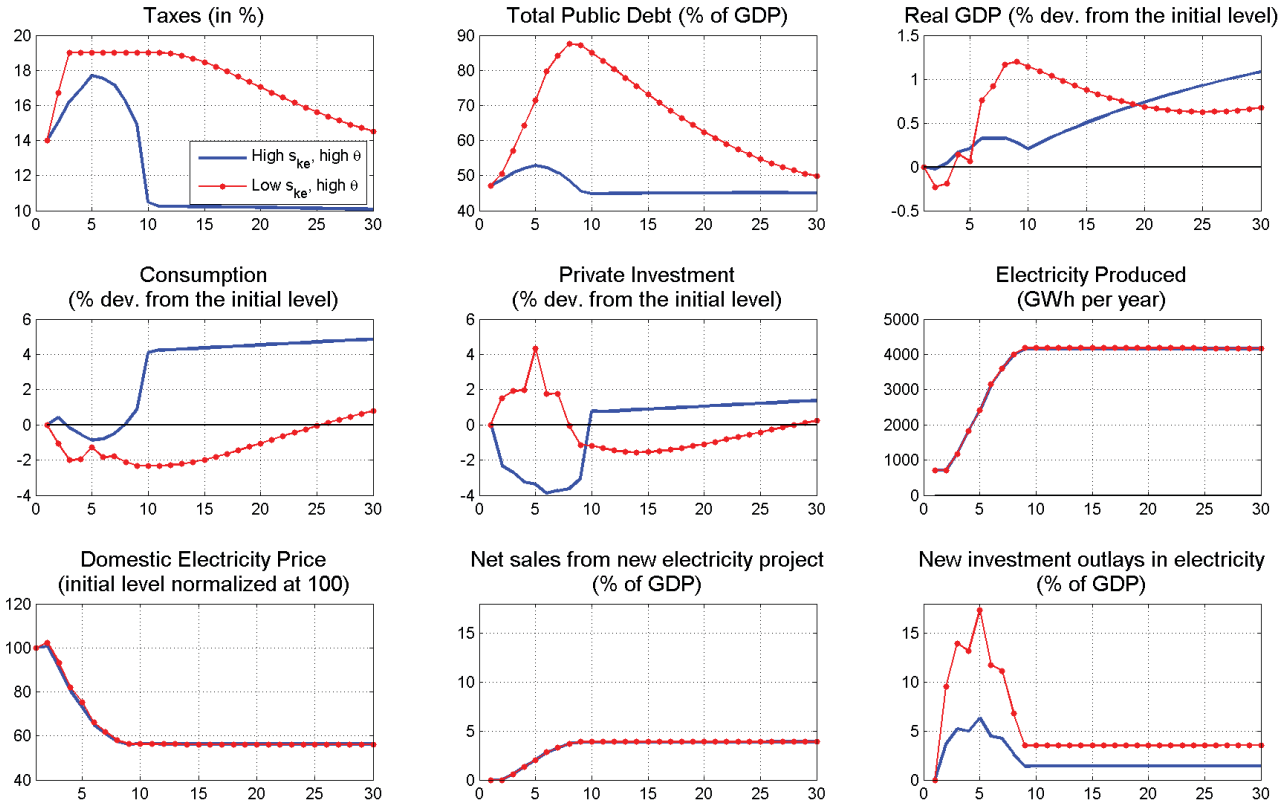


Figure 4: The impact of having lower efficiency.

One of the key challenges in implementing large projects is keeping the construction costs under control. It is not uncommon to see actual costs significantly exceeding the initial allocation. This could be due to unforeseen incumbencies, but also to inefficiencies in the construction phase. Hydro-power projects are known to be especially prone to such overruns. As explained in the calibration section, to calibrate a potential cost overrun we use $s_{ke} = 0.4$. This represents a significantly higher project costs than the initial project estimates. However, it is lower than it would be implied by the outcomes of a similar project in South Africa, the Ingula dam. There are examples of projects with much higher cost overruns, but this case is sufficient to highlight the risks for a large project in Lesotho, a small country unable smooth out idiosyncrasies across other similar projects.

In figure 4, the blue line represents the scenario with high capacity, high efficiency, and commercial financing, while the red line is the scenario with the same assumptions, except with low efficiency. Given that building the dam is a discrete choice, there is no impact on electricity production and sales. The change is in the costs that the government has to endure, at its apex Lesotho is spending around 17% of GDP in the project, instead of 6%. Moreover, one can see by comparing red lines in panel 7 and 8 of figure 4 that there are barely any positive financial flows in the long run as the inefficiency persists in the maintenance phase.

Higher outlays translate into larger fiscal gaps to be covered. This is done by raising taxes and issuing debt. The assumption that the authorities are allowing the size of the needed fiscal adjustment (i.e. increase in indirect tax rate) to be at most 5 percentage points is binding. The remaining fiscal needs are covered by external debt, which goes up to almost 90% of GDP (from less than 50 percent of GDP initially). This debt is allowed to be gradually paid off, but at the cost of keeping the tax rate relatively high over 30 years after the completion of the project. Moreover, such high debt levels could undermine fiscal sustainability and provoke a debt crisis, with a spike in interest rates and loss of market access, if the government is unable to credibly commit to keep high taxes for a long period of time. Note that this run effect cannot be included in a perfect foresight model as there cannot be any commitment problem but should still be considered by policy makers involved in the project. Furthermore, the interest rate on external debt is currently exogenous and endogenizing it with respect to public debt would make the prospects for debt sustainability monotonically worse.

Consumption stays below the initial level for more than two decades and never reaches the same level as the scenario with higher efficiency. The path for private investment may seem counterintuitive at first glance as it is now crowded in the first 7 periods. The reasons are twofold: first, the dam is much more expensive to build, so more non-tradables are required; second, the fiscal adjustment is delayed thanks to higher public debt, which implies that more resources are temporarily available to invest in the non-tradables necessary to build the dam. This effect is reversed, if we do not allow foreign debt, where crowding out would be higher with bigger project costs. The fact that, in this scenario, GDP increases more in an earlier stage of the project is a direct consequence of the increase of private investment.

The main takeaway from this simulation is that risks are very high with projects of this size that are subject to various shocks. A moderate shock (commensurate to the experience with the construction of Ingula pump storage scheme) could have significant implications for the country's welfare and debt sustainability. Additional scenario that one might consider is the event that the government decides to abandon the project during the project construction. Which means the government would incur initial costs before beginning to generate any benefit. This case is clearly worse off than not carrying out the project in the first place.

B.1. The impact of delaying fiscal adjustment

In this subsection, we briefly explore the impact of delaying or watering down fiscal adjustment in the case when the project turns out to be more expensive than planned.

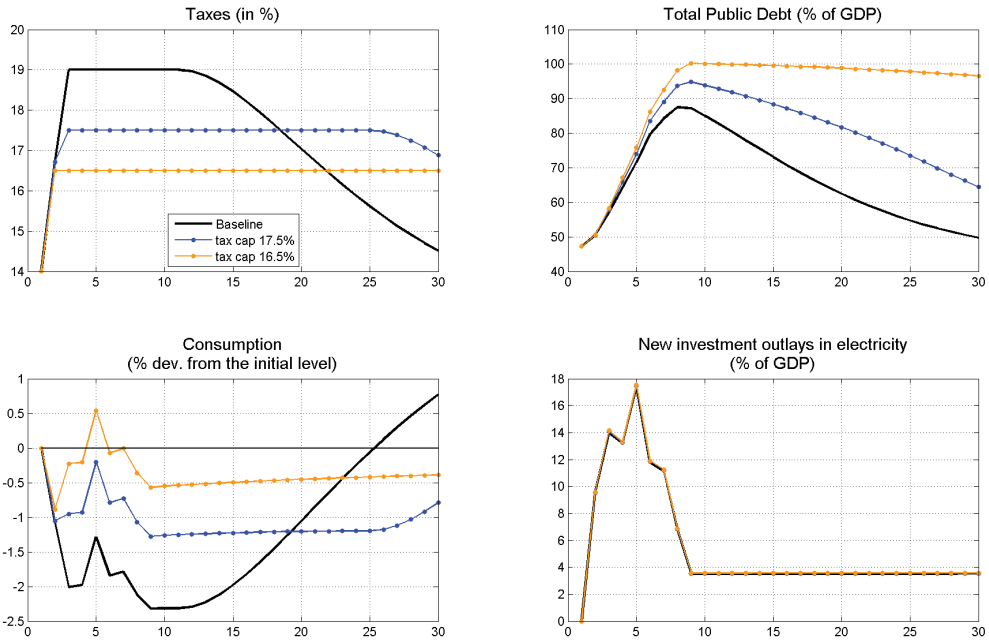


Figure 5: The effect of allowing less fiscal adjustment.

Figure 5 displays what happens if the cap on indirect taxes is lower than the 19% that was present in the previous simulation (the black line).
The blue and the orange lines represent the result with a cap on taxes of 17.5% and 16.5% respectively.

There is no change to the public investment path as it can be seen on the fourth panel. Unsurprisingly, taxes are initially lower during the construction, but remain high for much longer time and revert much less to the previous level. Public debt reaches 100% of GDP and remains high for an extended period. Reducing the ceiling on tax rate below 16% would not allow the model to converge as the debt schedule becomes explosive, implying that this investment is not technically feasible without some domestic costs through higher taxes.

As taxes do not rise immediately, consumption faces less crowding out in the initial period, however it remains low for very long: it takes 33 and 63 years, respectively, to come back at the initial level in the calibrations with 17.5% and 16.5% caps. Even in the longer run consumption never reaches the baseline level.

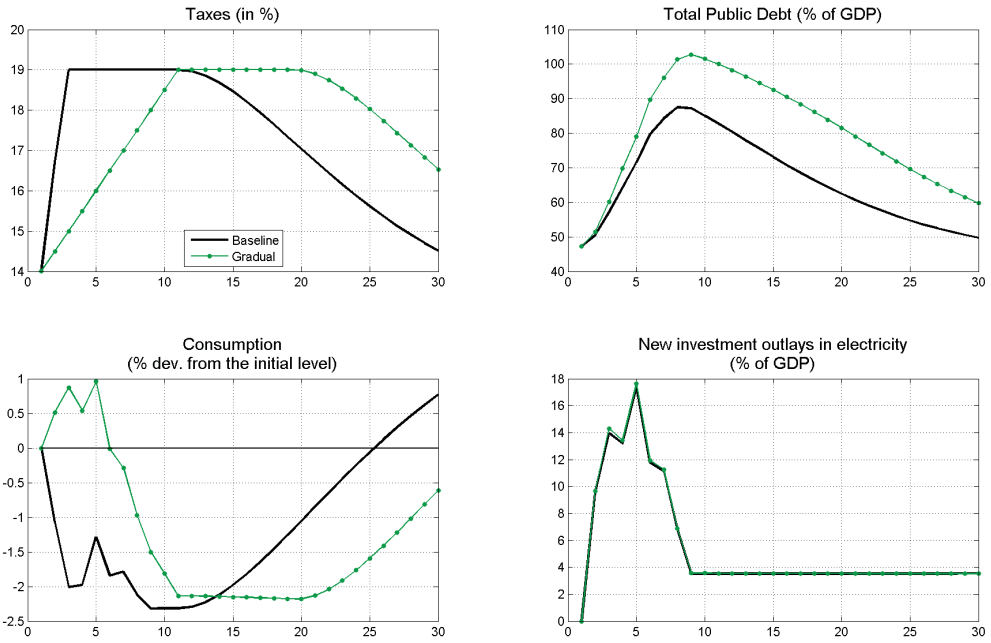


Figure 6: The effect of allowing slower fiscal adjustment.

Not only allowing a lower fiscal adjustment can be detrimental to the country, also delaying it poses sizable risks. In figure 6, we compare the calibration of the previous section (black line) with one where taxes are allowed to rise 0.5 percentage points each period, from the initial 14% to 19% (green line).

In this case, the dip in consumption in just pushed forward, but not avoided. The costs are that public debt exceeds 100% of GDP and consumption never reaches the same level as the baseline.

These two examples demonstrate the importance of taking timely and appropriate fiscal adjustments in order to avoid increase in public debt beyond sustainable levels and undercutting the welfare in the long term.

C. High Efficiency and low capacity factor

In this section we look into the implications of not finding sufficient demand for the produced electricity.

In figure 7, we compare the scenario with lower capacity utilization and a higher selling price against the baseline with high efficiency, commercial financing and high capacity. The reason to use

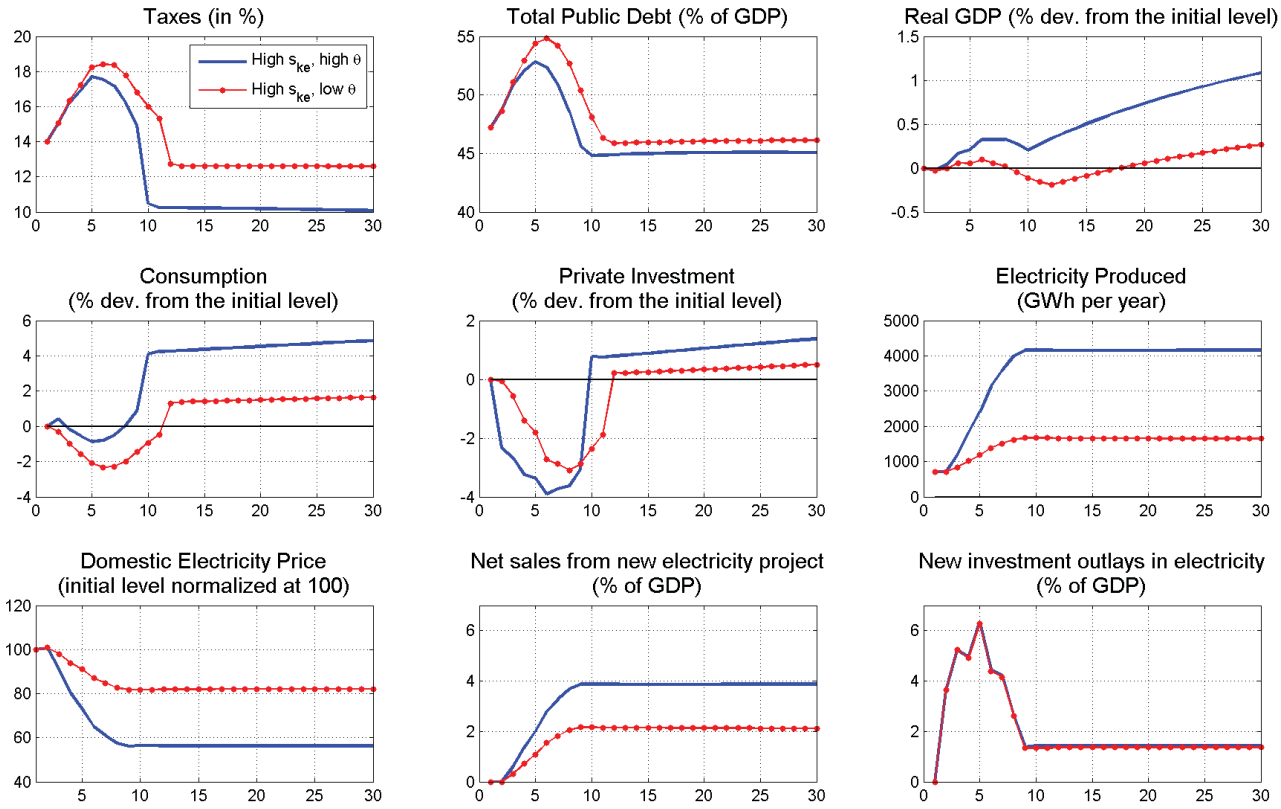


Figure 7: High versus low capacity with high efficiency

higher price is that, given the nature of pump storage power plants, reduced sales of electricity can feasibly take place during high demand hours. θ is now equal to 0.09 implying selling electricity for slightly more than 15 hours per week. This number is considerably lower than the 0.32 implied by purchasing electricity during all available times when the off-peak rate is in place but plausible as explained in the calibration section.

Investment in energy capital does not change, as it can be seen from the ninth panel of figure 7. What changes is the amount of electricity produced (sixth panel) and the corresponding sales (eight panel). As costs are the same but revenues are lower, in the long run the project generates lower financial benefits; these are around 0.5% of GDP instead of more than 2% present in the previous calibration. This implies higher financing needs which are covered by higher taxes and higher public debt, which reaches 55% of GDP. Consumption is crowded out more and never reaches the long run level (implied by the scenario with higher demand), as taxes cannot be lowered further.

By looking at financial flows, this scenario appears similar to the one with lower efficiency. However, they are not equivalent. The reason is that, in the model, there are other general equilibrium feedback mechanisms. First, there is no additional impact on the production side: non-tradables do not receive the boost and do not drive output up. Second, the local energy market is strongly affected as it does not receive large additional amounts of cheap electricity. This impact can be seen in panel five and six, with the price of domestic electricity declining by only 20 percent, compared to 50 percent in the other scenario.

GDP follows a flatter path for two reasons. The direct one is that energy exports are a component of GDP, so lowering them directly translates into a decrease. The indirect reason comes from the fact that the economy is less productive as there is less cheap energy available in the domestic market.

It may seem counterintuitive in this scenario, that private investment is crowded out less in the initial period. This behavior arises from the Euler equation for the household: with high demand it expects high consumption windfalls in the future even without investing privately. Therefore, it consumes as much as possible today and lets investment go down. On the other hand, with low demand, these high consumption windfalls are not going to happen. So the household lets consumption decrease relatively more and at the same time invests relatively more. The reason is that, in the current scenario, future consumption depends more on private behavior.

On the policy side, this calibration highlights the importance of reaching an agreement during the bilateral negotiations that would allow sufficient production of electricity at a new plant. Even with an extremely high efficiency, the project if going to crowd out consumption for a decade and public debt increases up to 55% of GDP. Moreover this does not even consider the possibility of replicating the costs of the Ingula dam, which we analyze in the next section.

D. Low Efficiency and low capacity factor

The project could incur substantial cost overruns even when demand is low, as the two processes are independent. Should this happen, the outcome for Lesothos economy would be abysmal, as figure 8 shows.

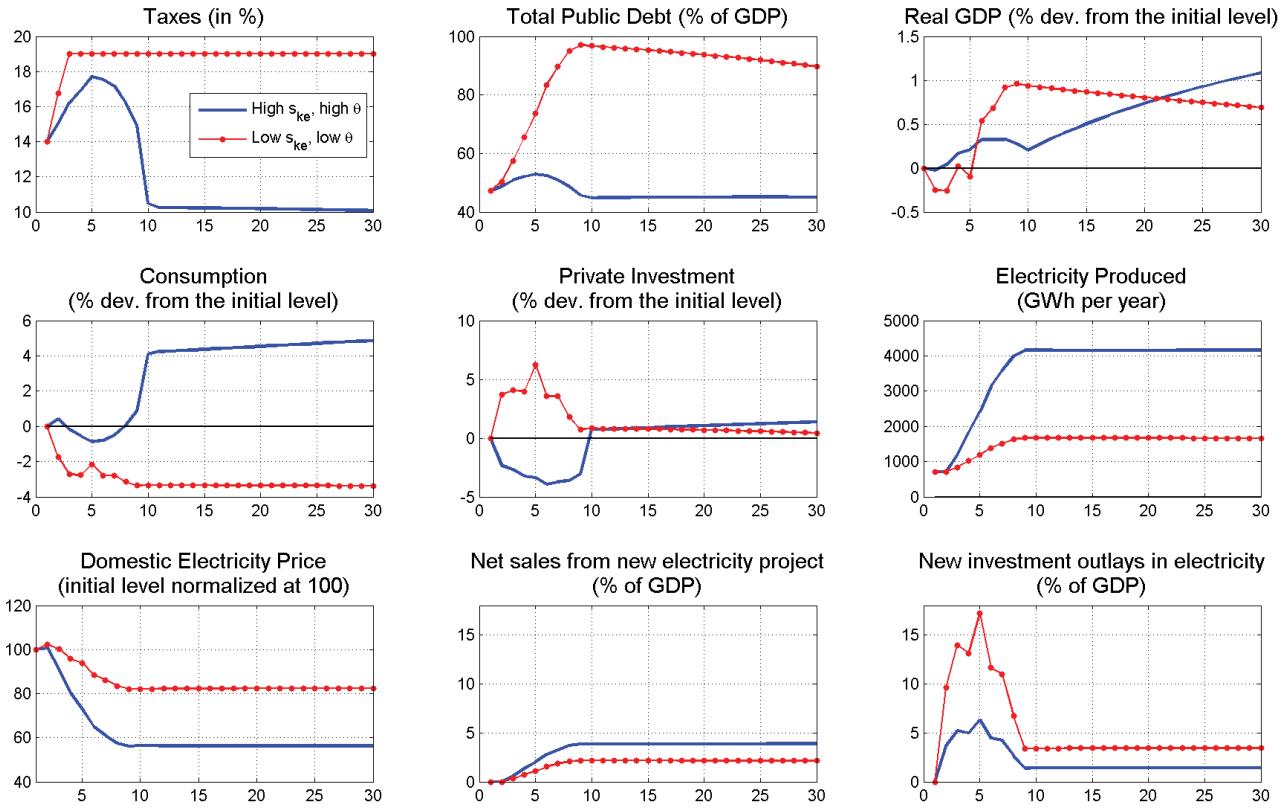


Figure 8: High versus low capacity and high versus low efficiency

The long run financial flows from the project are negative as electricity sales are lower than the maintenance costs. The comparison between the red lines in the eighth and ninth panel illustrates this point. From the last panel it is also noticeable that investment costs reach 17% of GDP as efficiency is low. These big costs, which are never recovered, map into taxes and public debt. Taxes reach in two periods the 19% cap and do not fall for more than 30 years. Public debt jups to almost 100% and remain relatively high for a considerable period. In this simulation the government is technically solvent, but the level of commitment (in terms of tax policy) required to sustain it is such that sustainability is seriously called into question.

As taxes drain a lot of resources for prolonged time, consumption drops and remains under the

pre-project steady state level. The increase in private investment and GDP in the construction period mirrors the other scenario with low efficiency: construction needs are high and the presence of public debt allows for net inflows of resources in the economy. These two features together allow private investments to take place. However, the general equilibrium impact of having cheap electricity in domestic production are dampened as foreign electricity demand is low.

This scenario points out that both low efficiency and low capacity can materialize at the same time and have big negative impact on welfare and debt sustainability.

V. Conclusion

Lesotho has relatively rich hydro resources, which the country is taking advantage of through the joint projects with South Africa that are aimed at increasing supply of water to the densely populated areas of South Africa. In addition, the project initiators conceived an idea of developing hydropower production based on these resources. Initial total project cost estimates indicate that the project could be very costly for the country of this size: about 50 percent of current GDP. Given that Lesotho is unlikely to raise concessional resources to cover the entire project, a large portion will need to be financed from commercial sources. This puts onus on the implications of project costs and financing on Lesotho's debt sustainability [insert footnote referencing to the latest DSA (forthcoming 2015 article iv staff report] and macroeconomic stability. Before embarking on such a project, it is critically important to assess macroeconomic implications of the project and identify the critical factors that could undermine the project success. The model based approach presented in this work allows to form internally consistent projections which can complement the traditional Excel-based DSA.

Based on the approach by Buffie et al. (2012) we use open-economy dynamic general equilibrium model, incorporating electricity-sector specific assumptions and investigate the macroeconomic effects of construction of a large hydroelectric power plant. In particular, we are interested how project outcomes are sensitive to two specific assumptions regarding the efficiency of project construction s and amount of electricity to be sold to South Africa (capacity utilization factor θ). In terms of project financing, while it is currently widely expected that the bulk of the financing would be on commercial terms, as a benchmark, we use the (highly unlikely) option of raising domestic consumption tax rate (with its implications on growth and welfare). Once the project is completed and generates cash flow, the foreign debt can be repaid in case external financing was used and the tax rate can be reduced. Moreover, the sales of electricity domestically and to South Africa would provide a sizable contribution to the GDP and, in the latter case, boost exports. However, the model did not specifically focus on the current account issues. The improvements in the current account stem largely from the project itself, determined by its feasibility from the fiscal and debt sustainability viewpoint, not real exchange rate adjustments.

As Table 3 shows, the scenario with high capacity utilization ($\theta = 32\%$) and efficient project im-

	A	B	C	D
Input				
θ	32%	32%	9%	9%
s_{ke}	1	0.4	1	0.4
Output				
Top Public Debt[b]	52.8%	87.2%	54.8%	96.9%
Public Debt 30[a,b]	45.0%	49.5%	46.1%	88.8%
Top Tax Rate	17.7%	19%	18.4%	19%
Tax Rate 30[a]	10.0%	14.4%	12.6%	19%
Lowest Consumption[c]	-0.8%	-2.2%	-2.3%	-3.4%
Consumption 30[a,c]	5.1%	1.0%	1.7%	-3.3%
Top New Energy Investment[b]	6.3%	17.3%	6.3%	17.2%
Project Financial Flow 30[a,b]	2.5%	0.4%	0.8%	-1.2%

[a]The value of the variable 30 periods after the beginning of the project

[b]Variable in percent of GDP

[c]Variable in percent deviation from the initial steady state

Table 3: Scenarios Summary Table

plementation ($s = 1$) generates largest benefits for economy, irrespective of the mode of financing. It allows for a relatively small drop in the consumption during the project period, and raises the consumption by 5 percent, permanently. In the scenarios where either capacity utilization is low or inefficient construction, the drop in intermediate consumption is larger and gains in long-term consumption are much smaller (1-1.7 percent). Moreover, public debt rises substantially in the transition to up to almost 90% and a sizable fiscal adjustment is needed, with taxes rising by up to 5 percentage points of GDP for more than a decade. Still, the project produces some long run macroeconomic benefits, albeit small. The scenario with both factors being unfavorable produces the dismal results. Not only does the consumption decline during the construction, it also permanently declines by more than 3 percent, while the public debt is doubled.

These results underscore the importance of ensuring that the costs of the project are kept within the budget. Unfortunately, cross-country experience of these kinds of projects show that usually the costs exceed the amounts that were initially estimated, even in countries with strong project assessment and implementation capacities as shown by Ansar et al. (2014). Moreover, the utilization capacity will largely depend on the long-term agreement with South Africa on the amounts to be sold after the project is finished. Financial feasibility of the project would depend critically on the agreed amounts and the timetable. Related to this, although not discussed thoroughly in the paper, are the selling and purchasing prices at which Lesotho would agree with its neighbor to sell (during peak hours) and buy (off peak) electricity. The model assumption is to use the existing ESKOMs price schedule.

As outlined earlier, in realizing this project the Lesotho authorities would face several key challenges. First, the need to agree with South Africa on the long-term power-purchasing agreement that would stipulate the amounts and prices of sold and purchased electricity. Second, the authorities have to improve the existing project preparation and implementation capacity.

The construction of a hydropower plant under the second phase of Lesotho Highlands Water Project could potentially be beneficial for the country. However, several key conditions need to be met. Moreover, while the construction of the project would boost the economy, the project is not designed to generate large employment in the long term. The authorities still are faced with the challenge of developing a vibrant and competitive private sector. The power plant project would be complementary (in the sense of reducing the constraints of electricity shortages) to any economic activities of the private sector.

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Appendix: Robustness of the Electricity Share in Production of Tradables and Non-Tradables

In this appendix we check the robustness of the assumption on the electricity share in the production of tradable and non-tradable goods.

It is a priori unclear whether Lesotho should face a higher or lower electricity intensity than the EU, the USA, China, or Japan. There are several possible reasons for a low electricity intensity in developing countries; one could be that the subsistence agricultural sector and the informal sector need little electricity to produce. Another reason could be that even sectors which are electricity intensive in industrial economies are less so in developing countries, as they optimally use more abundant and cheap resources as labor rather than scarce and outage-prone resources as electricity. On the other hand, it may be the case that Lesotho faces higher electricity shares than industrial economies as it specializes in sectors which are relatively energy intensive as textiles and mining.

For these reasons, we check the impact of both increasing and decreasing β_x and β_n. From our baseline of $\beta_x = 0.02$ and $\beta_n = 0.01$ in the first robustness check we decrease both numbers by 50% to $\beta_x = 0.01$ and $\beta_n = 0.005$. In the second check we increase them by 50% to $\beta_x = 0.03$ and $\beta_n = 0.015$ respectively. All the simulations are run in the case of low efficiency and high demand from South Africa, with the baseline being exactly the scenario presented in subsection B. of the scenarios section.

Figure 9 presents the results of this simulation. As the fourth panel shows there is no change in the path of public investments in electricity, which is costly due to low efficiency. Moreover, even the percent change in domestic electricity prices does not change. This is because the increase in the quantity of electricity is the same across scenarios.

The two parameters under investigation enter the production function of the domestic goods; therefore, it is unsurprising that the main impact of varying them is seen in the output growth. If the economy is 50% more electricity intensive than in the baseline, the project raises output by roughly 0.4 percentage points at the first growth peak after 9 years, which reaches a differential of 0.6 percentage points after 30 years. Conversely, if the economy is 50% less electricity intensive than in the baseline, the project will lower output by similar magnitudes.

The variation in output has a direct impact on consumption, this implies that an economy more electricity intensive would benefit relatively more from the project. In the higher β_x and β_n case, the percent increase in consumption keeps rising steadily: it stands 0.46 percent higher after 9 periods and reaches 0.91 percent higher after 30 periods. The size of the decrease in consumption in the opposite case is similar, with a decrease of 0.46 percent after 9 periods and of 0.91 percent after 30.

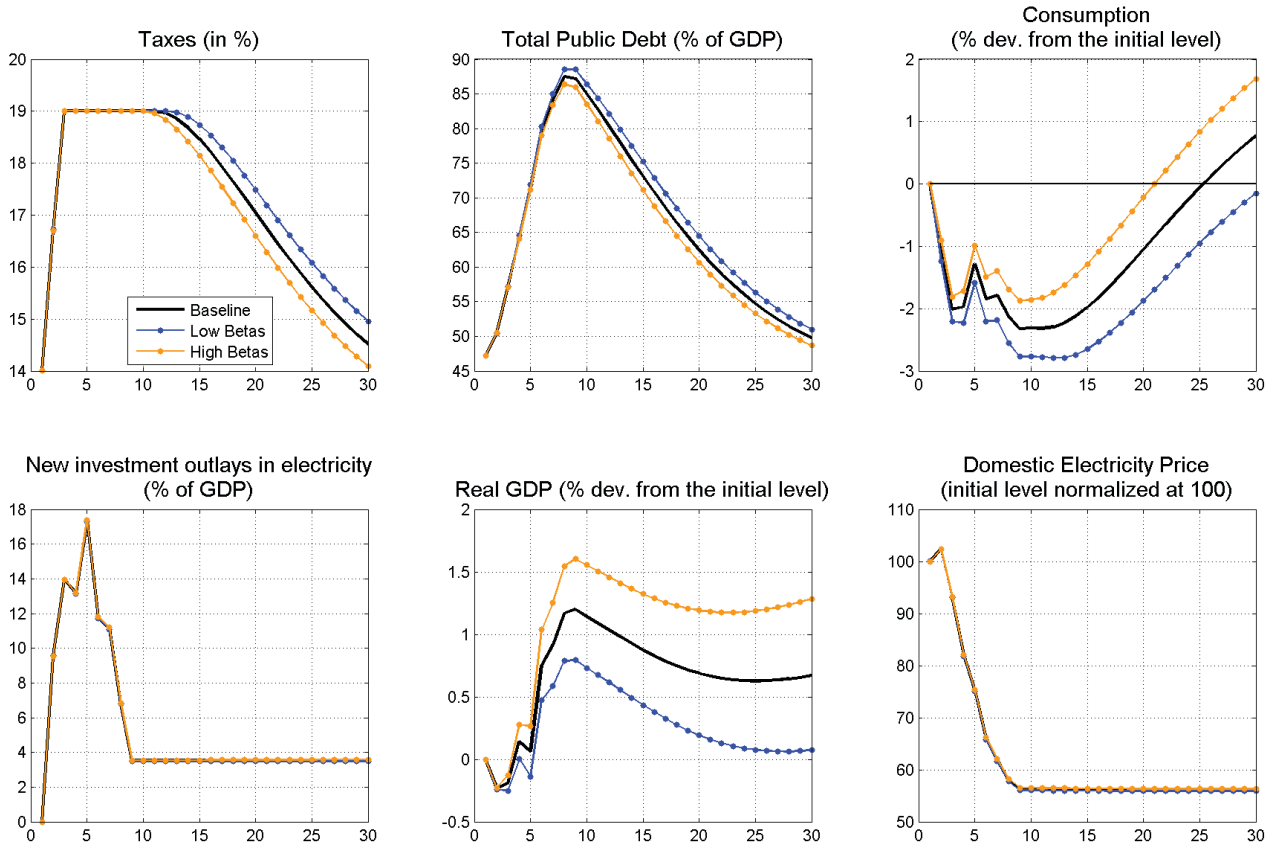


Figure 9: Robustness of β_x and β_n.

The private sector of the economy is quite sensitive to the electricity intensity, on the other hand, the fiscal sector does not experience much variation across regimes. Taxes and public debt follow closely their baseline values. In all three simulations taxes reach quickly 19 percent and stay there for a prolonged period of time. In the simulation with high β_x and β_n taxes start declining only one year before the baseline and in the simulation with low β_x and β_n they begin the declining path only one year after the baseline. Even in subsequent years the difference in the tax rate with the baseline never surpasses 0.5 percent. A similar observation carries through to public debt with the difference with the baseline being at most 2 percent, a small number considering the peak of public debt present in these simulations.

The robustness check presented in this appendix explores the sensitivity of the model to the choice of the parameters governing the electricity intensity of the production side of the economy. The outcome is that the welfare analysis is more sensitive to this assumption than the debt sustainability one. Consumption varies moderately across simulations whereas taxes and public debt do not.