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Natural Gas, Public Investment and Debt Sustainability in Mozambique

Giovanni Melina and Yi Xiong

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Prepared by Giovanni Melina and Yi Xiong

Authorized for distribution by Andrew Berg, Catherine Pattillo, and Doris C. Ross

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Abstract

Mozambique has great potential in natural gas reserves and if liquefied/commercialized the sum of taxes and other fiscal revenue from natural gas will, at its peak, reach roughly one third of total fiscal revenue. Recent developments in the natural resource sector have triggered a fresh round of much needed infrastructure investment. This paper uses the DIGNAR model to simulate alternative public investment scaling-up plans in alternative LNG market scenarios. Results show that while a conservative approach, which simply awaits LNG revenues, would miss significant current growth opportunities, an aggressive approach would likely meet absorptive capacity constraints and imply a much bigger (and, in an adverse scenario, unsustainable) build-up of public debt. A gradual scaling up approach represents indeed a desirable path, as it allows anticipating some, though not all, of the LNG revenue and, even in an adverse scenario, keeping public debt at sustainable levels. Structural reforms affecting selection, governance and execution of public investment projects would significantly enhance the extent to which public capital is accumulated and impact non-resource growth and, ultimately, debt sustainability.

JEL Classification Numbers: E6; Q32
Keywords: Natural resources; Debt sustainability, Public investment, Mozambique, DIGNAR

Author's E-Mail Addresses: giovanni.melina.1@city.ac.uk; yxiong@imf.org

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I. INTRODUCTION

Mozambique is expected to become a major natural gas producer and liquefied natural gas (LNG) exporter in Sub-Saharan Africa. Oil companies have discovered tremendous natural gas reserves in the Rovuma Basin off the northern coast of the country. According to the business plans, liquefaction and transportation facilities are to be built, and by mid-2020s Mozambique would be exporting tens of million tons of LNG to the rest of the world, in turn bringing in billions of dollars of revenue back to the country each year. As is shown in this paper, developments in the natural gas sector will transform the landscape of the Mozambican economy. According to the results of the Fiscal Analysis of Resource Industries (FARI) model, if the LNG projects materialize as planned, LNG will become Mozambique's single largest exporting sector and contribute up to around one third of fiscal revenue.

Although LNG production is not projected to start until around 2020, Mozambique would see the impact of the LNG sector on the economy much sooner. In anticipation of future LNG revenues, the government expects to have easier access to financing and to be able to expand its public investment program before LNG production starts. Public investment can help close the infrastructure gaps, positively impacting productivity and hence non-LNG output and growth. This, in principle, should allow the rest of the economy to benefit from the LNG sector boom.

However, investment scaling-up has its limits. The level of public debt increases along with investment scaling-up. As a result, if public investment is scaled up too quickly, debt levels will skyrocket to the extent that it may destabilize the economy. Moreover, if public investment increases too quickly, the degree of inefficiency is likely to increase as investment will more likely bump into absorptive capacity constraints and hence a bigger part of investment expenditures would be wasted. This would also impact debt sustainability.

We analyze these issues and evaluate the costs and benefits of public investment scaling-up through the lens of the "Debt, Investment, Growth and Natural Resources" (DIGNAR) model. This model is designed to analyze the public investment and growth nexus together with debt sustainability and natural resource revenue management in developing countries. The framework is based on a Dynamic Stochastic General Equilibrium (DSGE) model developed by Melina et al. (2013) at the Research Department of the IMF. DIGNAR merges the model for debt sustainability analysis in Buffie et al. (2012) with that for natural resource revenue management in Berg et al. (2013) and International Monetary Fund (2012), and introduces some additional features such as a public investment path that can potentially exhibit frontloading – the degree of which can be parameterized – and fiscal buffers, the lower bound of which represents a policy choice. As the analysis of the Mozambican case has a medium- to long-run horizon, we calibrate the model at an annual frequency.

Model parameters are calibrated to fit the context of Mozambique. We use the model to simulate output and public debt paths under different public investment strategies. These strategies include a *conservative approach*, in which public investment does not increase at all before LNG production starts; a *gradual approach*, in which public investment rises gradually before LNG production starts; and an *aggressive approach*, in which investment increases massively early on.

The modeling framework also allows us to assess the impact on output and debt of uncertainties that typically surround LNG markets. We compare between two scenarios: a baseline scenario in which LNG production is on track and LNG prices follow a path observable in normal times, and an adverse scenario in which average LNG production is down by 20 percent and there are negative LNG price shocks of a size typically observable in oil and gas market crises.

Our main results suggest that public investment has a great potential of turning LNG wealth into higher non-resource growth in Mozambique. More specifically, a gradual public investment scaling-up anticipating some but not all future LNG revenue would be appropriate in order to balance Mozambique's tremendous infrastructure investment needs with the uncertainty regarding LNG production/revenue. In contrast, due to absorptive capacity constraints, an aggressive approach is not likely to yield tangibly better growth outcomes and poses threats to debt sustainability.

The remainder of the paper is structured as follows. Section II provides an overview of LNG developments in Mozambique. Section III presents the results of the FARI model in projecting LNG revenue. Section IV provides some background on Mozambican public investment. Section V presents the DIGNAR model and its predictions on the macroeconomic effects of public investment scaling-ups. Section VI concludes. The model equilibrium conditions and calibration are appended to the paper.

II. Natural Gas Sector in Mozamique: An Overview

Mozambique has long been recognized to have potential in hydrocarbon resources. The Pande and Temane gas fields were discovered in the 1960s, but civil unrest in the 1970s and 1980s halted in gas exploration activities. Exploration resumed slowly in the 1990s, partly reflecting low oil prices. Activity accelerated in the early 2000s as oil and natural gas prices rose globally. In 2003 Sasol, a South African oil company, carried out extensive exploration in the Pande/Temane onshore blocks in the South of the country, increasing gas reserves to 5½ trillion cubic feet (TCF). Mozambique started to export gas to South Africa through pipelines in 2004.

Although the early gas discoveries and commercial activities were concentrated in the South, the future of natural gas sector in Mozambique lies in the northern region. Geographic survey results show that the Rovuma basin, offshore close to the Mozambique-Tanzania border, has great potential in hydrocarbon reserves. The Mozambican government has contracted exploration and production agreements with a number of international partners since 2006. Explorations to date revealed enormous amount of recoverable natural gas reserves in offshore Areas 1 (operations led by the US-based oil company Anadarko) and 4 (operations led by the Italian oil company ENI). Total gas reserves discoveries in the two areas combined reach 200 TCF and are expected to increase further. The discoveries thus far have made Mozambique's natural gas reserves the second largest among all sub-Saharan African countries, comparable to Nigeria's (Table 1).

The natural gas discoveries in the Rovuma basin created the possibility for Mozambique to become a major natural gas exporter. The offshore nature and geographic location of the gas reserves made it economically feasible to liquefy and transport natural gas to South and East

Asia, where the demand for natural gas has been growing fast. The size of confirmed reserves can support large-scale LNG production over a long time horizon.

Table 1. Countries with World's Largest Proven Natural Gas Reserves*

(in trillions of cubic feet)

Country	Reserves
Iran	1187
Russia	1163
Qatar	885
Turkmenistan	618
United States	300
Saudi Arabia	291
United Arab Emirates	215
Mozambique	**200**
Venezuela	195
Nigeria	180
Algeria	159
Australia	133
Iraq	127
China	108
Indonesia	105

* As of end-2012, except for Mozambique.

Sources: BP Statistical Review of World Energy June 2013, Mozambican authorities, and IMF staff calculations.

The current plan of Anadarko and ENI is to jointly develop an onshore LNG manufacturing site which is near Areas 1 and 4, and build four LNG plants ("trains") to produce LNG. LNG can be directly shipped to the destinations from the manufacturing site. We assumed that each train will have the capacity of producing 5 million tons of LNG per year, and that the construction of one train takes approximately five years. Given the scale of the construction work and logistical constraints, it is not possible to build the four trains simultaneously. Construction of the first train is expected to begin in 2014-15, and the first train is expected to start production before 2020. Construction of the second train would start one year after that of the first train, and production would begin one year later as well. Construction of the third and fourth trains could start 2 years after the second train. Maximum capacity would be 20 million tons per year once all four trains become operational.[2]

The production plan described above is used as the working assumption for the analysis of this paper. The planned four LNG trains are expected to consume only a small fraction – 20-24 TCF – of the proven natural gas reserves in the Rovuma Basin. Technically, the natural gas reserve can support a much larger scale of LNG production in the Rovuma basin. However, the realization of LNG production will depend on a lot of factors, such as world prices movements, finding investors and customers, securing financing, and construction

[2] Source: IMF (2013), Staff Report for the 2013 Article IV Consultation, IMF Country Report No. 13/200.

capacity constraints. Because of these uncertainties, we take the four-train LNG production scenario as the baseline for our analysis.

III. Predicting LNG Revenue: The FARI model

We projected the contribution of the LNG sector to GDP and revenue using the Fiscal Analysis of Resource Industries (FARI) model developed by the IMF Fiscal Affairs Department (FAD), the details of which can be found in IMF (2012). The FARI model forecasts the contributions of specific mining and/or petroleum projects to fiscal revenue, balance of payment, and national accounts. Inputs to the model include production, exports, cost structure and prices assumptions, as well as fiscal regime parameters.

Calibration of the FARI model to fit the context of the Mozambican LNG projects was done by two FAD technical assistance missions to Mozambique in 2012 and 2013. Based on their results, we updated the production and cost assumptions in the model to reflect the planned four-train project as described in the previous section.

The key assumptions for the LNG projects are as follows:

- **LNG production** is projected to start in 2020. Production in the first year is projected to be 5 million tons or a quarter of the full capacity, because only one of the four trains is expected to be operational in the first year. A second train will become operational by end-2020, boosting production to 10 million tons in 2021 and 2022. LNG production will reach the maximum capacity of 20 million tons per year in 2023.

- **Total investment** is projected at $40 billion over the project horizon, roughly half-half split between the upstream (natural gas extraction and initial processing) and the midstream (liquefaction). On the upstream side, the cost of upfront exploration and development is expected to reach $15 billion by 2021, and another $5 billion will be invested in drilling over the project horizon to maintain gas production levels. On the midstream, the construction of the LNG plants and supporting infrastructure is projected to cost $20 billion between 2014 and 2022.

- **Financing** for the investment will be 30 percent in equity and 70 percent in debt. Debt financing is assumed to be on commercial terms.

- **Separation of upstream (natural gas mining) and midstream (liquefaction).** Gas liquefaction will be under a separate entity from the upstream. The upstream gas mining company will have natural gas liquefied by the LNG plants and pay service fees to the midstream company. The internal rate of return (IRR) for the midstream project is assumed at 8 percent for the purpose of determining the cost of gas liquefaction.

- **LNG prices** will follow oil price movements over the medium term. We obtained oil price projections from the IMF April 2013 World Economic Outlook. A slope coefficient of 0.14 is applied to obtain medium term natural gas price projections. The LNG price is assumed to be constant in real terms over the long run from 2018 onwards.

- **Fiscal regime.** The fiscal regime for the natural gas activities comprises three main elements: a production tax (royalty), a production sharing agreement, and a corporate income tax levied on the profits of the contractors. Detailed fiscal rules are set out in the Exploration and Production Concession Contracts (EPCCs) negotiated between the government and the contractors. The EPCCs for Anadarko and ENI's explorations have both been signed in 2006. Representative parameters from existing EPCCs are used to calibrate the FARI model (Table 2). The terms of the two specific EPCCs remain confidential.

- **The R-factor** is a cost recovery parameter that determines the share of profit gas earned by the government. It is calculated as the ratio of the concessionaire's cumulative cash inflows, net of operating costs and tax, to its cumulative capital expenditures. According to the representative setting, the government's production share starts at 10 percent, and will gradually increase to 60 percent as the R-factor increases.

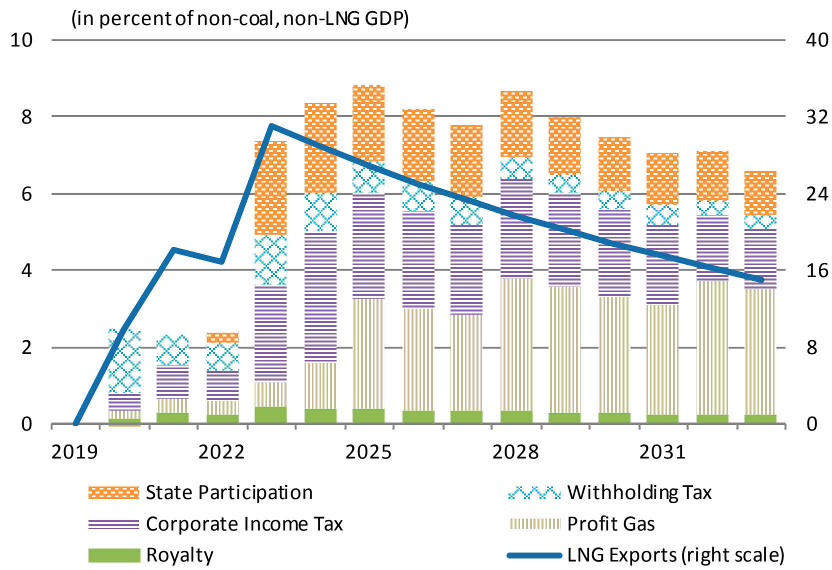
Table 2. Representative EPCC Parameters

Tax		Tax Rate
Royalty		2%
Cost recovery limit		65%
	R-Factor	Share
Profit Petroleum / Gas	1.0	10%
	2.0	20%
	3.0	30%
	4.0	50%
	> 4.0	60%
Corporate Income Tax		
In first 8 years from production start		24%
After first 8 years		32%
Dividend withholding tax		10%
Subcontractor withholding tax		20%

Source: National Petroleum Institute of Mozambique (INP).

FARI model results show that the natural gas projects would bring in significant economic benefits to Mozambique. Exports peak at 30 percent of non-oil GDP, and the sum of taxes and other fiscal revenue from natural gas, at its peak, reach 9 percent of non-oil GDP, or roughly one third of total fiscal revenue (Figure 1). The government's share is projected to be small in the first few years, when gas production volume is small and the bulk of the revenue is used to cover costs. Revenue is expected to surge in 2023 when all four LNG trains become operational, and would gradually increase afterwards. The composition of revenue also changes over the project horizon. At first the main source of revenue is subcontractor withholding tax. Corporate income tax and payoff from public enterprise participation will pick up a few years after the projects start. Revenue from EPCC production sharing will be small at the beginning, but the share of profit gas will increase gradually along with the R-factor. Eventually, profit gas will become the main source of revenue, accounting for more than half of total LNG-related fiscal revenue. Results from the FARI model are used to calibrate the natrual resource revenue in the DIGNAR model (see Section V).

Figure 1. LNG Sector Contribution to GDP and Fiscal Revenue



Sources: Mozambican authorities, and IMF staff estimates from the FARI model.

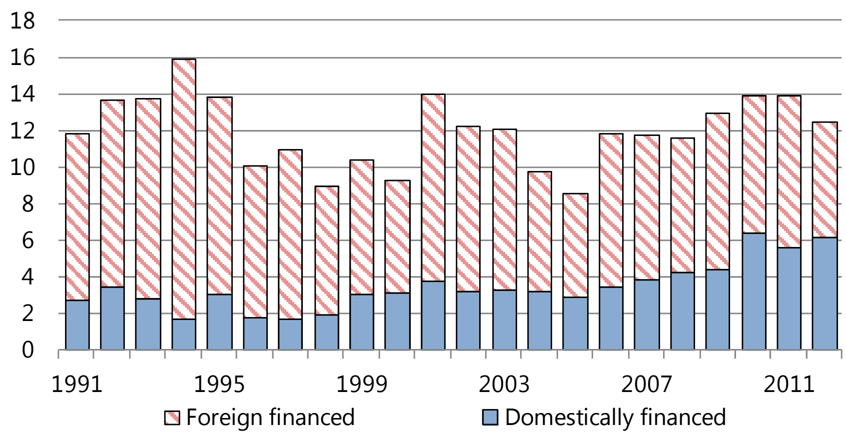
IV. Public Investment in Mozambique

Mozambique has had relatively high public investment levels throughout its post-conflict history. Public capital expenditure exceeded 10 percent of GDP in 16 out of the past 20 years (Figure 2). The high level of investment has been supported by foreign grant and debt financing, and increasingly by domestic financing in recent years. Public investment went largely into infrastructure: roads, ports, power plants and electricity, water and sanitation, schools, and hospitals. The need for infrastructure investment was significant: existing infrastructure was either destroyed or poorly maintained, if at all, during the long-lasting civil war. However, it is costly to build and maintain infrastructure in a thinly populated country (population of about 25 million with 0.8 million square kilometers of land--twice the size of California). Twenty years after the end of conflict, infrastructure gaps remain one of the major constraints to growth and development (Dominguez-Torres and Briceno-Garmendia, 2011).

Recent developments in the natural resources sector have triggered further infrastructure investment. Towns and cities are expanding near the coal mines in Tete province. Railways and ports need to be expanded to ship coal from the landlocked mines overseas. Maputo, the capital of Mozambique, is becoming increasingly densely populated and requires upgrades in roads, electricity, and other urban infrastructure.

The government is trying to address these needs by expanding public investments. In the process, the public debt stock is rising. What are the tradeoffs here? How can they strike the right balance between development needs, investment efficiency, and preserving fiscal sustainability? The rest of the paper tries to answer these questions by applying the DIGNAR model calibrated to fit the context of Mozambique.

Figure 2. Mozambique: Public Capital Expenditure, 1991-2012



Source: Mozambican authorities.

V. THE MACROECONOMIC EFFECTS OF INVESTMENT SCALING-UPS

A. The DIGNAR Model

The "Debt, Investment, Growth and Natural Resources" (DIGNAR) model is designed to analyze the public investment and growth nexus together with debt sustainability and natural resource revenue management in developing countries.

In particular, the framework is a small-economy model with limited asset market participation to capture the presence of agents that do not have access to financial markets in developing countries. The production side of the model exhibits (i) a traded goods sector featuring learning-by-doing externalities to capture the effects of the Dutch disease that may arise due to natural resource booms; (ii) a non-traded goods sector; (iii) and a natural resource sector.

A typical firm in the traded (T) and non-traded (N) good sectors produces output $y_{j,t}$, $j = \{T, N\}$, according to technology

$$y_{j,t} = z_j \left(k_{j,t-1}\right)^{1-\alpha_N} \left(L_{j,t}\right)^{\alpha_N} \left(k_{j,t-1}\right)^{\alpha_G}, \quad j = T, N, \qquad (1)$$

where z_j is a total factor productivity scale parameter, $k_{j,t}$ is end-of-period private capital, $k_{j,t}$ is end-of-period public capital, α_N is the labor share of sectoral income and α_G represents the output elasticity with respect to public capital.

The model also features inefficiencies and absorptive capacity constraints for public investment, and a time-varying depreciation rate of public capital to capture lack of maintenance, in line with the empirical literature for developing economies (see Gupta et al. 2011, among others). Dominguez-Torres and Briceno-Garmendia (2011) estimated that out of Mozambique's \$664 million expenditure per year on infrastructure during the late 2000s, as much as \$204 million was lost to inefficiencies annually.

To reflect this, effective investment, $\tilde{g}^I{}_t\left(\gamma_t^{GI}\right)$ – where $\gamma_t^{GI} \equiv \frac{g_t^I}{\bar{g}^I} - 1$ is the percent deviation of public investment from its initial steady state, $\bar{g}^I$ – is given by

$$\tilde{g}_t^I = \left\{ \begin{array}{ll} \bar{\varepsilon} g_t^I & \text{if} \gamma_t^{GI} \leq \bar{\gamma}^{GI} \\ \bar{\varepsilon}\left(1+\bar{\gamma}^{GI}\right)\bar{g}^I + \varepsilon\left(\gamma_t^{GI}\right)\left[1+\gamma_t^{GI} - \bar{\gamma}^{GI}\right]\bar{g}^I & \text{if} \gamma_t^{GI} > \bar{\gamma}^{GI} \end{array} \right\}, \tag{2}$$

where $\bar{\varepsilon} \in [0,1]$ represents steady-state efficiency and $\varepsilon\left(\gamma_t^{GI}\right) \in (0,1]$ governs the efficiency of the portion of public investment exceeding threshold $\bar{\gamma}^{GI}$, in terms of percent deviation from the initial steady state. In particular, we assume that $\varepsilon\left(g_t^I\right)$ takes the following specification:

$$\varepsilon\left(g_t^I\right) = \exp\left[-\varsigma_\varepsilon\left(\gamma_t^{GI} - \bar{\gamma}^{GI}\right)\right]\bar{\varepsilon}. \tag{3}$$

In other words, if government investment expenditure deviates from the initial steady state more than $\bar{\gamma}^{GI}$, the efficiency of the additional investment decreases to an extent proportional to the size of the deviation. This mechanism captures absorptive capacity constraints in developing countries. The severity of absorptive capacity constraints is measured by parameter $\varsigma_\varepsilon \in [0,\infty)$.

The law of motion of public capital is

$$k_{G,t} = \left(1 - \delta_{G,t}\right)k_{G,t-1} + \tilde{g}_t, \tag{4}$$

where $\delta_{G,t}$ is a time-varying depreciation rate of public capital, which captures the idea that lack of maintenance shortens the life of existing capital. Details on how $\delta_{G,t}$ is modeled are provided in Appendix A.

The path of public investment scaling-ups is chosen according to the country's plans and/or to assess alternative scenarios. Public investment can be frontloaded and the degree of the frontloading is linked to the degree of investment inefficiency.

As far as fiscal policy is concerned, the model has a fund where any positive difference between inflows (including natural resource revenue) and outflows (including investment expenditures) are saved and the lower bound of this fund is a policy choice. The fund is drawn down when such a difference is negative. However, when the fund reaches a chosen lower bound, then one or more fiscal instruments react to close it either instantaneously or by temporarily allowing accumulation of public debt and satisfying the government intertemporal budget constraint in the long run. In the case of Mozambique – where natural resource exploitation is a recent phenomenon and virtually no fiscal buffers have been yet accumulated – we set a lower bound of zero for the fund, which effectively becomes a non-negativity constraint for government assets. The model allows four fiscal instruments to close the fiscal gap (consumption tax, labor income tax, government consumption and government transfers). For simplicity, where needed, we allow only the consumption tax to stabilize debt in the long run and leave the other instruments at their initial steady state. Although the use of other instruments, combined or in isolation, imply somewhat different macroeconomic dynamics, the bottom-line of the results outlined below is robust to such choices.

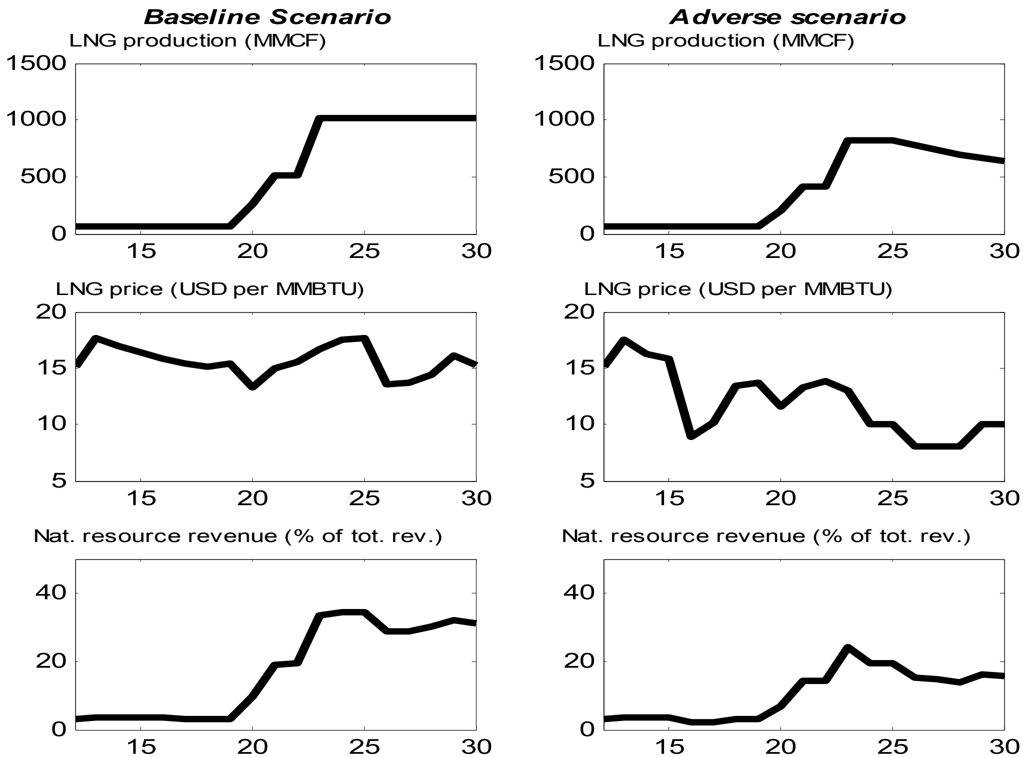
For full details of the model, the derivation of equilibrium conditions, and calibration see the Appendix.

B. Scenarios of LNG production

Natural resource markets are typically surrounded by substantial uncertainty. One big source of uncertainty is the price volatility which characterizes commodity markets. However, non-renewable natural resources are also subject to exhaustibility, i.e. to the fact that the endowment of a particular natural resource will be wiped out completely at a certain point in the future. In addition, there may be cases in which, while the endowment of a natural resource has not been exhausted, market conditions may make its extraction and distribution unfeasible or un-economical and, as a consequence, its production stops or considerably diminishes. This uncertainty is reflected in the revenue that the government may raise from natural resources. Although in many cases natural resource sector output is also dependent on public investment, it is not the case for Mozambique because the LNG sector is mostly offshore and does not depend on any public infrastructure.

In order to show the consequences of shocks to LNG revenue in the Mozambican case, we analyze two scenarios that we depict in Figure 3:

Figure 3. LNG Revenue Simulations in the Baseline and Adverse Scenarios.



1. a ***baseline scenario*** in which the LNG production is in line with that used for the revenue projections obtained from the FARI model (as discussed in Section III) and a price path observable in normal times. In particular, production starts in 2020 and reaches a level of 1 billion cubic feet by 2023. In this scenario LNG revenue rises to a peak of 40 percent of total fiscal revenues.

2. an ***adverse scenario*** in which average LNG production is smaller (80 percent of the level in the baseline scenario), there are negative LNG price shocks of a size typically observable in oil and gas market crises as well as an earlier exhaustion of gas reserves. Hence, this scenario features negative shocks both to production and prices. In this scenario LNG revenues reach a peak of 20 percent of fiscal revenues.

C. Simulation results

In this section, we simulate the effects of alternative public investment scaling-up plans in Mozambique. These plans represent alternative policy decisions that government may take and are set exogenously to the model. DIGNAR represents a tool to assess the macro-fiscal implications of such plans. In particular, the effects of the alternative investment plans on non-LNG growth and their fiscal consequences are reported in Figures 4 and 5, respectively. In the figures, public investment, public capital, and non-LNG GDP are reported in real terms as percentage deviations from the trend growth path without additional resource revenue from the 2012 level, the initial steady state for the simulations. The simulations take into account projections or assumptions of the LNG price, LNG production, public investment, aid and the endogenous response of the macroeconomy to these shocks. As a result they abstract from other shocks that may likely affect macroeconomic outcomes. Similarly, additional non-LNG GDP growth refers to the component of non-LNG growth to be ascribed to public investment scaling-ups.

We focus on three alternative approaches to public investment scaling-ups.

1. Under a ***conservative approach*** no additional public investment is made until LNG production starts in 2020, then it gradually increases up a level 50% higher than 2012 in real terms.

2. Under a ***gradual approach*** public investment is gradually increased in anticipation of LNG production and revenue and it reaches its new level by the time production is in place.

3. Under an ***aggressive approach*** public investment is massively frontloaded and exhibits substantial overshooting (up to 8 points of GDP).

Figure 4. Public Investment Scaling-Ups and Growth Outcomes.

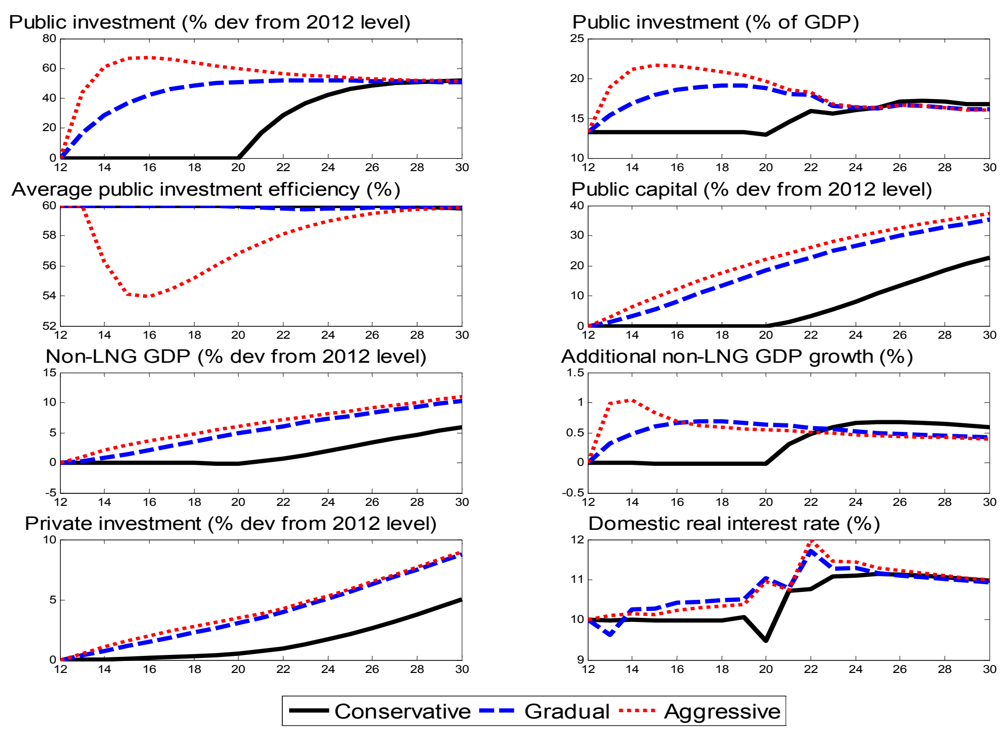
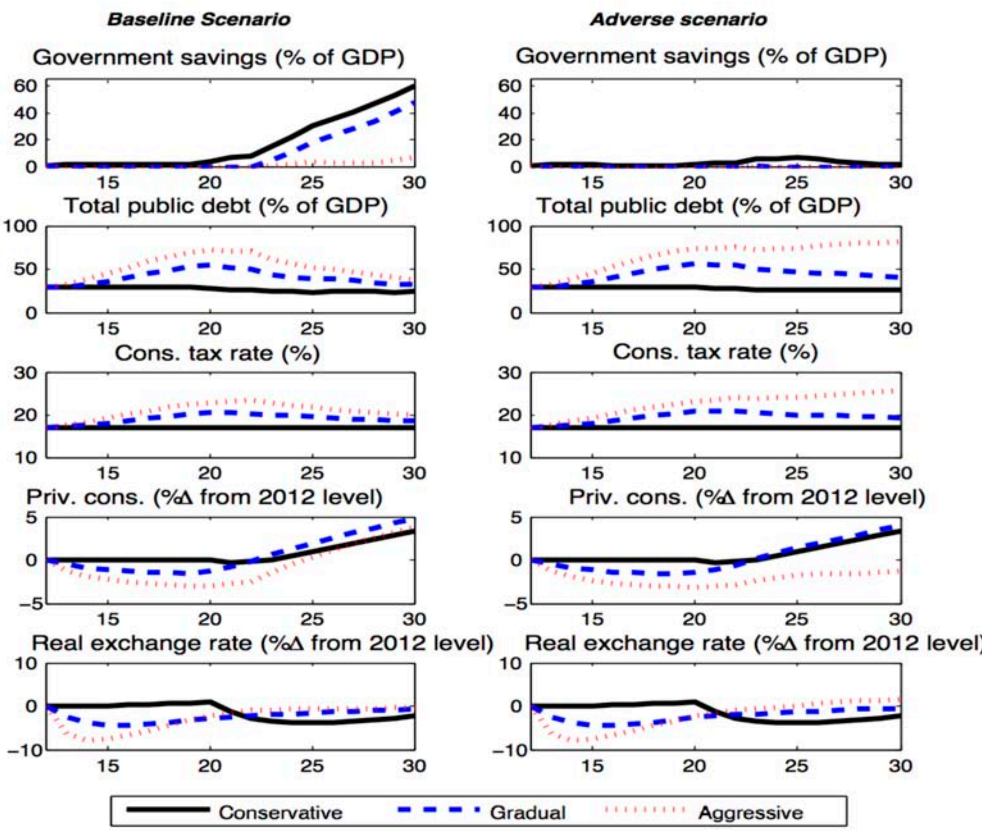


Figure 5. Fiscal and Real Exchange Rate Consequences of Public Investment Scaling-Ups.



Across the three approaches, total public investment expenditures over the simulation horizon differ. Hence, by comparing outcomes, the model allows choosing both the level and degree of frontloading appropriate to the country's characteristics and goals.

A *conservative approach* simply awaits the LNG revenues. Spending on growth-enhancing investment projects would increase only in the years when LNG production starts. Public debt does not rise as a share of GDP and declines over the longer term, thus no fiscal adjustment is required and hence no reduction in private consumption is generated. The start of LNG production would allow building strong fiscal buffers in the form of government savings (up to 60 percent of GDP in the baseline scenario of the LNG market).

The *gradual approach* allows anticipating some of the LNG revenue. Public debt rises gradually to a peak of 50 percent of GDP in 2019-20, then declines over the longer term to more sustainable levels, thus the required fiscal adjustment (e.g. in terms of tax increases) is small and this is reflected in a smaller initial fall in private consumption. Unless a conservative approach is adopted, in the case of Mozambique – where natural resource exploitation is a recent phenomenon and virtually no fiscal buffers have been yet accumulated -- debt accumulation and/or fiscal adjustments take place as soon as the investment plan starts. In the baseline scenario, the full roll-out of LNG production would allow building fiscal buffers in the form of government savings from 2023 on. Both in the baseline and in the adverse scenario, in the long run the level of private consumption is highest under the gradual approach. Private investment is crowded in by public investment. In fact, the increase in public capital increases the productivity of private capital and this translates into a higher level private investment and an increase in the domestic real interest rate.

An *aggressive approach* would fully anticipate future LNG revenues and increase public investment spending massively early on. However, due to absorptive capacity constraints, the higher investment spending delivers a similar build-up in the public capital stock as under the gradual approach. In fact, the fall in the efficiency on the additional public investment makes average efficiency fall by 6 percent points. The effect on the additional non-LNG growth and on the increase in private investment and consumption generated is dampened similarly. In fact only for two years non-LNG growth would be higher in with the aggressive approach; in the medium to long run the additional growth generated is similar to the gradual approach. An aggressive approach implies a much bigger build-up of public debt to 70 % of GDP in 2019-20, and would require a painful fiscal adjustment in order to service the accumulated debt, leading to a more pronounced fall in private consumption.

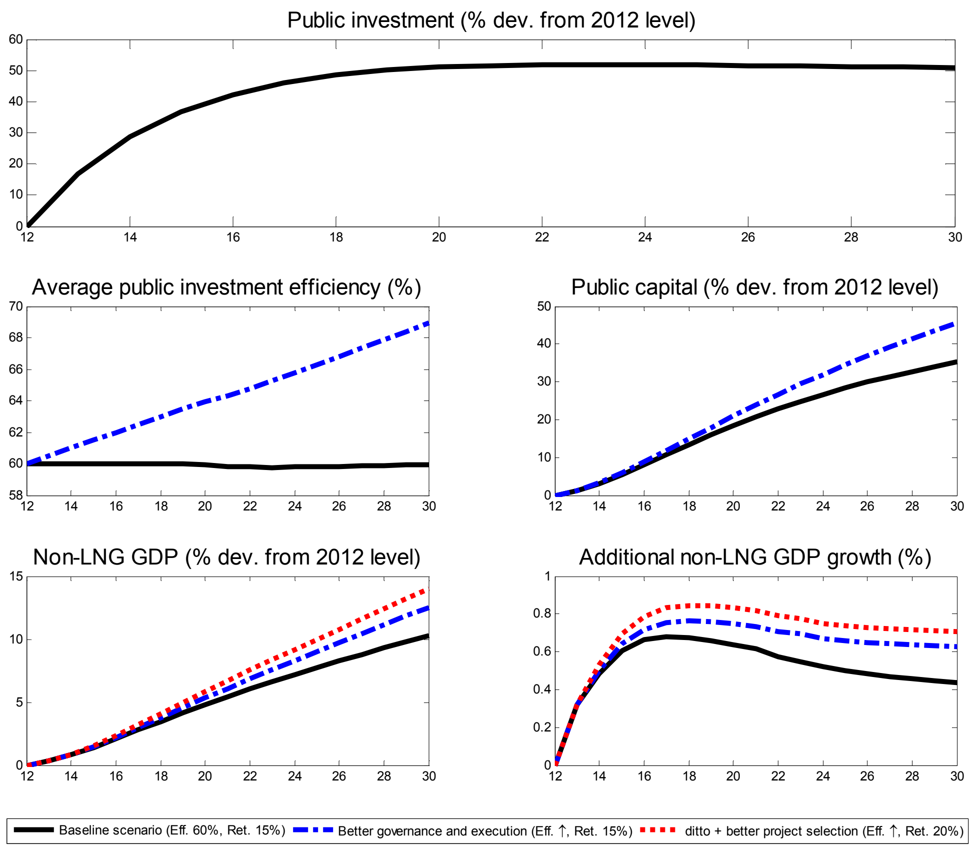
In addition, the aggressive approach, although the calibration assumes a mild home bias for the additional government investment (due to the fact that much of the investment goods are imported in low-income countries), leads to a relatively more pronounced appreciation of the real exchange rate (a downward movement in the charts implies an appreciation). This feeds into a relatively lower output in the traded sector, exacerbated by the presence of the learning-by-doing externality in that sector. Hence Dutch disease effects are more likely with an aggressive approach than with a gradual one.

In an *adverse scenario* with lower LNG production, lower LNG prices and an earlier exhaustion of gas reserves, there would be no room to build up significant fiscal buffers. Public debt would (i) not rise under the *conservative approach*, (ii) rise faster under a *gradual approach* than in the baseline; (iii) rise explosively under an *aggressive approach*, requiring painful and sustained fiscal adjustment without stopping the accumulation of debt. As reported in the calibration section, these simulations assume that at least half of recurrent infrastructure costs are covered by user fees. Failure to collect fees would exacerbate debt sustainability risks.

D. Structural reforms: the impact of governance and project selection

We also use DIGNAR to simulate the effects of structural reforms in the Mozambican economy. For example, if over time, institutions, governance, management practices are improved, public investment becomes, on average, more efficient this can be captured as an increase in the value of ε_t. In other words the proportion of public investment expenditure that effectively augments the stock of public infrastructure becomes larger. If investment projects are better designed, selected, and implemented, the average real return of investment increases. This can be captured by the value of α^G, which in turn determines the value of the net return of public capital in the initial steady state. In Figure 5 we report the non-LNG growth effect of such experiments. Given lack of history on the Mozambican experience in investing natural resource revenue in public infrastructure, it is difficult to conjecture plausible improvements along these two dimensions. Therefore, we opt for showing one among many possible examples of good policy in which the country is able to ameliorate the quality of its institutions, and the fact that policies affecting the efficiency of public investment expenditures and the productivity of infrastructure projects are powerful instruments for achieving superior macroeconomic performances. In particular, we let ε_t increase from 60% to almost 70% over 18 years. This positively affects the accumulation of the capital stock relative to the baseline scenario. Moreover, we simulate an improvement in project selection capacity/process by raising the annual net economic return on public investment at the initial steady state from 15 to 20 percent. Over time, these two sets of structural reforms enhance the extent to which public capital affects the productivity of private factors for production with a more positive impact on growth and incomes. In the example provided the combined effect of the two measures is an increase in the additional non-LNG GDP growth rate (relative to baseline) of more than half percentage point over a period of more than 15 years. More modest (bigger) improvements in institutional arrangements would clearly deliver a more moderate (superior) additional non-LNG GDP growth.

Figure 6. The Effects of Improvements in Project Selection and Better Governance and Execution



VI. CONCLUSION

The Rovuma basin, located off the northern coast of Mozambique and close to the Mozambique-Tanzania border, has great potential in natural gas reserves. FARI model results show that the natural gas projects can bring significant economic benefits to Mozambique, and the sum of taxes and other fiscal revenue from natural gas could, at its peak, reach 9 percent of non-oil GDP, or roughly one third of total fiscal revenue.

Recent developments in the natural resources sector have triggered a fresh round of infrastructure investment. Indeed, the need for infrastructure investment is significant. Public investment scaling-up can help unlock Mozambique's growth potential. However, if debt-financed public investment scaled up too rapidly, it may also lead to high debt ratios or bump into efficiency constraints.

In this study, we used the DIGNAR model to simulate alternative public investment scaling-up plans in alternative LNG market scenarios. We considered three different approaches towards public investment scaling-up: a gradual approach, a conservative approach, and an aggressive approach. In sum, a gradual public investment scaling-up anticipating some but not all future LNG revenue would be appropriate given Mozambique's infrastructure investment needs and the uncertainty regarding LNG production/revenue. The gradual approach outperforms the other two approaches under both the baseline scenario, in which the LNG project materializes as planned, and the adverse scenario, in which Mozambique suffers negative shocks to both production and prices. Under the gradual approach, public debt rises gradually in preparation of LNG production, but then declines over the longer term to more sustainable levels, even in an adverse scenario.

In comparison, a conservative approach that simply awaits LNG revenues is not desirable, because it postpones potential additional growth benefits by almost a decade. At the same time, an aggressive approach, which fully anticipates future LNG revenues and increases public investment spending massively early on, is not desirable either. In fact, the higher investment spending delivers a similar build-up in the public capital stock as under a more gradual approach. In addition, an aggressive approach implies a much bigger build-up of public debt which would become unsustainable in an adverse scenario with lower-than-planned LNG production and lower LNG prices.

Why is public investment not "the more, the merrier?" Given that LNG revenues will eventually come, why not start investing immediately so that the economy can immediately benefit? The simulation results from the model envisage two specific constraints facing Mozambique in light of the upcoming LNG revenue:

- Firstly, public investment scaling-up inevitably runs into the rule of diminishing rate of return. Investment inefficiencies may arise from many fronts: poor planning, higher-than-expected costs, bad governance, corruption, supply bottlenecks, and lack of complementary infrastructure. The more investment projects that are starting at the same time, the more likely that some of them would be poorly selected, mismanaged, or run into supply bottlenecks. At some point, the cost of inefficiencies would outweigh the benefits from bringing the investment upfront.

- Secondly, there are risks to the realization of natural resources wealth. History of LNG prices and experiences from other countries show that uncertainties are large in both production volume and prices of LNG. An aggressive investment scaling-up that anticipates all future LNG revenue would fully expose Mozambique to the downside risks, leading to unsustainable debt path under the adverse scenario of negative shocks to LNG production and prices.

The policy implications from this study are straightforward. Mozambique needs to strike the right balance between public investment and debt sustainability. The authorities need to have an integrated investment plan to track and coordinate investment projects undertaken in different sectors and under different line ministries. Debt levels need to be monitored closely, and debt sustainability analysis should be conducted at least annually to ensure that the build-up of debt is on a sustainable path.

To overcome the risk of adverse shocks to LNG production and prices, the public investment strategy should anticipate only a portion of projected revenue from the LNG sector. The increase in debt-financed investment should be moderate such that the debt path would remain sustainable even under the adverse scenario. Mozambique should not follow the aggressive approach to public investment, under which debt stock would explode under the adverse scenario.

The paper also shows the importance of structural reforms to improve investment efficiency. In the context of Mozambique, such structural reforms include the preparation and implementation of an Integrated Investment Program that strengthens the project selection process and coordination; capacity building for project appraisal and evaluation capacity; and improving governance and execution of public investment projects. If Mozambique could improve on these fronts, in particular reducing investment inefficiency and improving the return of public capital, the public capital stock would build up more rapidly and would become more conducive to private sector growth. The end-result would be an even higher positive impact on growth, incomes and debt sustainability.

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APPENDIX

A. DIGNAR model details

Households

Let us assume a continuum of infinitely lived households distributed over the unit interval. A fraction ω of households have access to capital markets where they can trade contingent securities and own firms. These agents are commonly referred to as *financially unconstrained*, *optimizing* or *Ricardian*. The remaining fraction $1-\omega$ of agents are *financially constrained* in that they do not own any asset, do not have any liabilities and in each period they just consume all of their income. These agents are commonly labeled as *rule-of-thumb* or *hand-to-mouth* consumers.

Let index OPT denote optimizing households and ROT denote rule-of-thumb households. Both types of agents consume a composite good c_t^i, for $i = OPT, ROT$, which in turn is a constant-elasticity-of-substitution (CES) aggregate of the traded good, $c_{T,t}^i$, which can be produced domestically or imported, and the domestic non-traded good, $c_{N,t}^i$. Thus, the consumption basket reads as

$$c_t^i = \left[\varphi^{\frac{1}{\chi}} \left(c_{N,t}^i\right)^{\frac{\chi-1}{\chi}} + (1-\varphi)^{\frac{1}{\chi}} \left(c_{T,t}^i\right)^{\frac{\chi-1}{\chi}} \right]^{\frac{\chi}{\chi-1}}, \qquad \forall i = OPT, ROT \qquad \text{(A1)}$$

where φ indicates the non-traded good bias and $\chi > 0$ is the intra-temporal elasticity of substitution.

Let $p_{T,t}$, and $p_{N,t}$ be the relative prices of goods T and N relative price of traded goods to composite consumption, respectively. Minimizing total consumption expenditure, subject to consumption basket (1), yields the demand functions for each good. Let the composite consumption be the numeraire of the economy and assume that the law of one price holds at the level of traded goods, then $s_t \equiv p_{T,t}$ represents also the real exchange rate (defined as the price of one unit of foreign consumption basket in terms of the domestic consumption basket). This implies, that in real terms the price of one unit of consumption is $1 = \varphi p_{N,t}^{1-\chi} + (1-\varphi) s_t^{1-\chi}$.

Both types of agents provide labor services $L_{T,t}^i$ and $L_{N,t}^i$, $\forall i = OPT, ROT$, to the traded and the non-traded sector, respectively and total labor effort, L_t^i, has a CES specification to capture the fact that hours worked in the two sectors are not perfect substitutes,

$$L_t^i = \left[\delta^{-\frac{1}{\rho}} \left(L_{N,t}^i\right)^{\frac{1+\rho}{\rho}} + (1-\delta)^{-\frac{1}{\rho}} \left(L_{T,t}^i\right)^{\frac{1+\rho}{\rho}} \right]^{\frac{\rho}{1+\rho}}, \qquad \forall i = OPT, ROT \qquad \text{(A2)}$$

where δ is the steady-state share of labor in the non-traded sector and $\rho > 0$ is the intra-temporal elasticity of substitution. Let $w_{T,t}$ and $w_{N,t}$ be the real wages paid in sectors T and N, respectively, and w_t be the real wage index. Maximizing the household's total labor income $w_t L_t^i = \; w_{T,t} L_{T,t}^i + w_{N,t} L_{N,t}^i$, subject to aggregate labor (5), yields the labor supplies for each sector and the real wage index, $w_t = \left[\delta w_{N,t}^{1+\rho} + (1-\delta) w_{T,t}^{1+\rho}\right]^{\frac{1}{1+\rho}}$.

Optimizing Households

A typical optimizing household seeks to maximize its inter-temporal utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(c_t^{OPT}, L_t^{OPT}\right) = E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{1}{1-\sigma} \left(c_t^{OPT}\right)^{1-\sigma} - \frac{\kappa^{OPT}}{1+\psi} \left(L_t^{OPT}\right)^{1+\psi} \right), \tag{A3}$$

subject to its budget constraint expressed in units of composite consumption,

$$\begin{aligned} &\left(1+\tau_t^C\right) c_t^{OPT} + b_t^{OPT} - s_t b_t^{OPT*} = \left(1-\tau_t^L\right) w_t L_t^{OPT} + \frac{R_{t-1}}{1+\gamma} b_{t-1}^{OPT} - \frac{R_{t-1}^*}{1+\gamma} s_t b_{t-1}^{OPT*} \\ &+ \Omega_{T,t} + \Omega_{N,t} + \vartheta^K \tau^K \left(r_{T,t}^K k_{T,t-1} + r_{N,t}^K k_{N,t-1}\right) \\ &+ s_t r m_t^* + z_t - \mu k_{G,t-1} - \Theta_t^{OPT*}, \end{aligned} \tag{A4}$$

where E_0 represents the expectation at time 0, $\beta \equiv [(1+\rho)]^{-1}$ is the subjective discount factor, ρ is the pure rate of time preference, σ is the inverse of the inter-temporal elasticity of substitution of consumption, $U\left(c_t^{OPT}, L_t^{OPT}\right)$ is the instantaneous utility function, ψ is the inverse of the intra-temporal elasticity of substitution of labor supply, κ^{OPT} is the disutility weight of labor, τ_t^C is the tax rate on consumption, τ_t^L is the tax rate on labor income, b_t^{OPT} are domestic government bonds that pay $R_t b_t^{OPT}$ units of the domestic consumption composite at time $t+1$, b_t^{OPT*} are liabilities towards the rest of the world that entail repayment of $R_t^* b_t^{OPT*}$ units of the foreign consumption basket, $\Omega_{T,t}$ and $\Omega_{N,t}$ are firms' profits in the traded and the non-traded sector, $\vartheta^K \tau^K \left(r_{T,t}^K k_{T,t-1} + r_{N,t}^K k_{N,t-1}\right)$, is a tax rebate that optimizing households are assumed to receive on the tax levied on the firms' return on capital,[3] rm_t^* are remittances from abroad, z_t are government net transfers, μ are user fees of public capital $k_{G,t}$, and $\Theta_t^{OPT*} \equiv \frac{\eta}{2}\left(b_t^{OPT*} - \bar{b}^{OPT*}\right)^2$ are portfolio adjustment costs associated to foreign liabilities, where η is a scaling factor and $\bar{b}^{OPT*}$ is the initial the steady-state value of private foreign liabilities.

Let λ_t be the Lagrange multiplier attached to the budget constraint (12), then households decisions are summarized by the first-order conditions with respect to c_t^{OPT}, L_t^{OPT}, b_t^{OPT} and b_t^{OPT*}. In addition we assume that on its foreign debt, the private sector pays a

[3] The assumption made is that, because of distortions in revenue mobilization, fraction ϑ^K of the tax revenue on private capital does not enter the government flow budget constraint. Poor institutions or corruption may be the channel through which part of the revenue is lost in the process of tax collection and earned, *de facto*, by private agents, which we assume to belong to optimizing households. In practical terms, this allows us to set a high enough tax rate, τ^K, which in turn allows us to match the observed low initial private investment flow and capital stock typical of LICs, while ϑ^K can be set to match the actual revenue that the government is able to raise.

constant premium u over the interest rate that the government pays on external commercial debt, $R_{dc,t}$:

$$R_t^* = R_{dc,t} + u. \tag{A5}$$

Rule-of-Thumb Households

Rule-of-thumb households have the same instantaneous utility function as optimizing households

$$U\left(c_t^{ROT}, L_t^{ROT}\right) = \frac{1}{1-\sigma}\left(c_t^{ROT}\right)^{1-\sigma} - \frac{\kappa^{ROT}}{1+\psi}\left(L_t^{ROT}\right)^{1+\psi}, \tag{A6}$$

and they are subject to the budget constraint

$$\left(1+\tau_t^C\right)c_t^{ROT} = \left(1-\tau_t^L\right)w_t L_t^{ROT} + s_t r m_t^* + z_t - \mu k_{G,t-1}, \tag{A7}$$

but they do not smooth consumption by solving an inter-temporal utility maximization problem. They simply consume all of their income period by period.

Aggregation

Aggregation across i implies that consumption and labor are given by the weighted average of their counterparts in both types of households:

$$c_t \equiv \omega c_t^{OPT} + (1-\omega)c_t^{ROT}, \tag{A8}$$

$$L_t \equiv \omega L_t^{OPT} + (1-\omega)L_t^{ROT}. \tag{A9}$$

Similarly, aggregate privately-owned government bonds and foreign liabilities read as

$$b_t \equiv \omega b_t^{OPT}, \tag{A10}$$

$$b_t^* \equiv \omega b_t^{OPT*}. \tag{A11}$$

Firms

In the economy there are three sectors: (i) a non-traded good sector indexed by N; (ii) a (non-resource) traded good sector indexed by T; and a natural resource sector indexed by O. We assume that the whole resource output is exported.

Non-Traded Good Sector

A typical firm in the non-traded good sector produces output $y_{N,t}$ according to technology

$$y_{N,t} = z_N\left(k_{N,t-1}\right)^{1-\alpha_N}\left(L_{N,t}\right)^{\alpha_N}\left(k_{G,t-1}\right)^{\alpha_G}, \tag{A12}$$

where z_N is a total factor productivity scale parameter, $k_{N,t}$ is end-of-period private capital, $k_{G,t}$ is end-of-period public capital, α_N is the labor share of sectoral income and α_G represents the output elasticity with respect to public capital.

There are convex costs of adjusting investment, hence, private capital evolves as

$$k_{N,t} = (1-\delta_N)k_{N,t-1} + \left[1 - \frac{\kappa_N}{2}\left(\frac{i_{N,t}}{i_{N,t-1}} - 1\right)^2\right] i_{N,t}, \tag{A13}$$

where $i_{N,t}$ represents investment expenditure, δ_N is private capital depreciation in sector N , and κ_N is the investment adjustment cost parameter.

The representative non-traded good firm maximizes its discounted lifetime profits weighted by the marginal utility of consumption of optimizing households, λ_t ,

$$\Omega_{N,0} = E_0 \sum_{t=0}^{\infty} \beta^t \lambda_t \left[p_{N,t} y_{N,t} - w_{N,t} L_{N,t} - i_{N,t} - \tau^K r^K_{N,t} k_{N,t-1}\right], \tag{A14}$$

where τ^K is a tax on the return on private capital $r^K_{N,t} k_{N,t-1} = \; (1-\alpha_N) p_{N,t} \dfrac{y_{N,t}}{k_{N,t-1}}$. Let $\lambda_t q_{N,t}$ be the Lagrange multiplier associated to the law of motion of capital, with $q_{N,t}$ being the sectoral Tobin's *q*. Then, firms' decisions are captured by the first-order conditions with respect to $L_{N,t}$, $k_{N,t}$, and $i_{N,t}$.

Traded Good Sector

Analogously to the non-traded good sector, a typical competitive firm in the non-traded good sector produces output $y_{T,t}$ according to technology

$$y_{T,t} = z_{T,t} \left(k_{T,t-1}\right)^{1-\alpha_N} \left(L_{T,t}\right)^{\alpha_N} \left(k_{G,t-1}\right)^{\alpha_G}. \tag{A15}$$

In this sector, total factor productivity, $z_{T,t}$, is subject to learning by doing externalities depending on last period's traded good output:

$$\frac{z_{T,t}}{z_T} = \left(\frac{z_{T,t-1}}{z_T}\right)^{\rho_{z_T}} + \left(\frac{y_{T,t-1}}{y_T}\right)^{\rho_{y_T}}, \tag{A16}$$

where $\rho_{z_T}, \rho_{y_T} \in [0,1]$ are structural parameters and variables with no time subscripts are steady-state values.

The law of motion of sectoral private capital is perfectly analogous to that of the non-traded good sector:

$$k_{T,t} = (1-\delta_T)k_{T,t-1} + \left[1 - \frac{\kappa_T}{2}\left(\frac{i_{T,t}}{i_{T,t-1}} - 1\right)^2\right] i_{T,t}. \tag{A17}$$

Also the representative traded good firm maximizes its discounted lifetime profits weighted by the marginal utility of consumption of optimizing households, λ_t ,

$$\Omega_{T,0} = E_0 \sum_{t=0}^{\infty} \beta^t \lambda_t \left[s_{T,t} y_{T,t} - w_{T,t} L_{T,t} - i_{T,t} - \tau^K r^K_{T,t} k_{T,t-1} \right], \tag{A18}$$

where $r^K_{T,t} = mc_{T,t} \ (1-\alpha_T) s_t \dfrac{y_{T,t}}{k_{T,t-1}}$ is the sectoral return on private capital. Let $\lambda_t q_{T,t}$ be the Lagrange multiplier associated to the law of motion of capital, with $q_{T,t}$ being the sectoral Tobin's *q*. Then, firms' decisions are captured by the first-order conditions with respect to $L_{T,t}$, $k_{T,t}$ and $i_{T,t}$.

Natural Resource Sector

As most natural resource production is capital intensive and much of investment in the resource sector is financed by foreign direct investment in low income countries, it is fair to represent natural resource production as exogenous process

$$\frac{\tilde{y}_{O,t}}{\tilde{y}_O} = \left(\frac{\tilde{y}_{O,t-1}}{\tilde{y}_O} \right)^{\rho_{yo}} \exp\left(\varepsilon^{yo}_t\right), \tag{A19}$$

where $\rho_{yo} \in (0,1)$ is an auto-regressive coefficient and $\varepsilon^{yo}_t : iid\, \mathsf{N}\left(0, \sigma^2_{yo}\right)$ is the resource production shock. We make a small-open-economy assumption in that the country's natural resource production is small relative to world production, hence the international commodity price (relative to the foreign consumption basket), $p^*_{O,t}$, is taken as given and evolves as

$$\frac{p^*_{O,t}}{p^*_O} = \left(\frac{p^*_{O,t-1}}{p^*_O} \right)^{\rho_{po}} \exp\left(\varepsilon^{po}_t\right), \tag{A20}$$

where $\rho_{po} \in (0,1]$ is an auto-regressive coefficient and $\varepsilon^{po}_t : iid\, \mathsf{N}\left(0, \sigma^2_{po}\right)$ is the resource price shock. Resource GDP in units of domestic composite consumption is

$$y_{O,t} = s_t p^*_{O,t} \tilde{y}_{O,t} . \tag{A21}$$

Let τ^O be the royalty rate on production. Then, the resource revenue collected each period is

$$t^O_t = s_t \tau^O p^*_{O,t} \tilde{y}_{O,t} . \tag{A22}$$

We assume that the resource output is not consumed domestically, as in low income countries almost the entire production is typically exported.

Government

Government expenditure

Government expenditure comprises government consumption, g_t^C , and public investment, g_t^I . Like private consumption, also government expenditure, $g_t \equiv g_t^C + g_t^I$, is a CES aggregate of the domestic traded good, $g_{T,t}$ and the domestic non-traded good, $g_{N,t}$. Thus, the government consumption basket reads as

$$g_t = \left[\nu_t^{\frac{1}{\chi}} \left(g_{N,t}\right)^{\frac{\chi-1}{\chi}} + \left(1-\nu_t\right)^{\frac{1}{\chi}} \left(g_{T,t}\right)^{\frac{\chi-1}{\chi}} \right]^{\frac{\chi}{\chi-1}}, \tag{A23}$$

where ν_t is the weight given to non-tradable goods in government purchases and $\chi > 0$ is the intra-temporal elasticity of substitution, assumed to be the same as in the private consumption composite.

Minimizing total government expenditures $p_t^G g_t = p_{N,t} g_{N,t} + p_{T,t} g_{T,t}$, subject to the government consumption basket (23), yields the demand functions for each good and the government consumption price index in terms of units of the domestic consumption composite, $p_t^G \equiv \left[\nu_t p_N^{1-\chi} + \left(1-\nu_t\right) s_t^{1-\chi} \right]^{\frac{1}{1-\chi}}$.

Note that ν_t is time-varying. As this paper focuses on the effects of additional government spending in the form of government investment, we allow the weight given to non-tradable goods for the additional government spending, ν_g , to differ from its steady state value, ν, i.e.

$$\nu_t = \frac{\left(p^G g\right)\nu + \left(p_t^G g_t - p^G g\right)\nu_g}{p_t^G g_t}. \tag{A24}$$

Public investment inefficiencies, absorptive capacity constraints and public capital depreciation

Public investment features inefficiencies and absorptive capacity constraints. To reflect this, effective investment, $\tilde{g}^I{}_t\left(\gamma_t^{GI}\right)$ – where $\gamma_t^{GI} \equiv \frac{g_t^I}{\bar{g}^I} - 1$ is the percent deviation of public investment from its initial steady state, $\bar{g}^I$ – is given by

$$\tilde{g}_t^I = \begin{cases} \bar{\varepsilon} g_t^I & \text{if } \gamma_t^{GI} \le \bar{\gamma}^{GI} \\ \bar{\varepsilon}\left(1+\bar{\gamma}^{GI}\right)\bar{g}^I + \varepsilon\left(\gamma_t^{GI}\right)\left[1+\gamma_t^{GI} - \bar{\gamma}^{GI}\right]\bar{g}^I & \text{if } \gamma_t^{GI} > \bar{\gamma}^{GI} \end{cases}, \tag{A25}$$

where $\bar{\varepsilon} \in [0,1]$ represents steady-state efficiency and $\varepsilon\left(\gamma_t^{GI}\right) \in (0,1]$ governs the efficiency of the portion of public investment exceeding threshold $\bar{\gamma}^{GI}$, in terms of percent deviation from the initial steady state. In particular, we assume that $\varepsilon\left(g_t^I\right)$ takes the following specification:

$$\varepsilon\left(g_t^I\right)=\exp\left[-\varsigma_\varepsilon\left(\gamma_t^{GI}-\overline{\gamma}^{GI}\right)\right]\overline{\varepsilon}. \tag{A26}$$

In other words, if government investment expenditure deviates from the initial steady state more than $\overline{\gamma}^{GI}$, the efficiency of the additional investment decreases to an extent proportional to the size of the deviation. This mechanism captures absorptive capacity constraints in developing countries. The severity of absorptive capacity constraints is measured by parameter $\varsigma_\varepsilon \in [0,\infty)$.

The law of motion of public capital is

$$k_{G,t}=\left(1-\delta_{G,t}\right)k_{G,t-1}+\tilde{g}_t, \tag{A27}$$

where $\delta_{G,t}$ is a time-varying depreciation rate of public capital, which captures the idea that lack of maintenance shortens the life of existing capital. This is operationalized by assuming that the depreciation rate increases proportionally to the extent to which effective investment fails to maintain existing capital:

$$\delta_{G,t}=\left\{\begin{array}{ll} \varphi\delta_G\dfrac{\delta_G k_{G,t-1}}{\tilde{g}_t} & \text{if } \tilde{g}_t<\delta_G k_{G,t-1} \\ \rho_\delta\delta_{G,t-1}+\left(1-\rho_\delta\right)\delta_G & \text{if } \tilde{g}_t\geq\delta_G k_{G,t-1} \end{array}\right\}, \tag{A28}$$

where δ_G is the steady-state depreciation rate, parameter $\phi \geq 0$ determines the extent to which poor maintenance produces additional public capital depreciation while $\rho_\delta \in [0,1)$ controls its persistence.

Resource windfalls and public investment policy

Let a resource windfall be a resource revenue that is above its original steady-state level, i.e. $t_t^O - t^O$, and f_t^* be a sovereign wealth fund (SWF) where the windfall is saved externally. Each period, the interest income of the SWF $s_t\left(R^{swf}-1\right)f_{t-1}^*$ – where R^{swf} is the gross real interest rate paid on foreign government savings – enters the government's flow budget constraint and the fund itself evolves as

$$f_t^*-f^*=\max\left\{f_{floor}-f^*,\left(f_{t-1}^*-f^*\right)+\frac{f_{in,t}}{s_t}-\frac{f_{out,t}}{s_t}\right\}, \tag{A29}$$

where f^* is the initial steady-state value of the SWF, $f_{in,t}$ represents the total fiscal inflow, $f_{out,t}$ represents the total fiscal outflow, and $f_{floor} \geq 0$ is a lower bound for the SWF that the government chooses to maintain. Every period, if the fiscal inflow exceeds the fiscal outflow, more resources are saved in the SWF.[4] If the sovereign wealth fund is above f_{floor} any fiscal

[4] In order to guarantee that the SWF is not an explosive process, we assume that – in the very long run – a small autoregressive coefficient $\rho_f \in (0,1)$ is attached to $\left(f_{t-1}^*-f^*\right)$. The model is solved at a yearly frequency for a 1000-period simulation horizon and coefficient ρ_f is activated after the first 100 years of simulations.

outflow that exceeds the fiscal inflow is absorbed by a withdrawal from the fund. Whenever the lower bound constraint binds, fiscal policy reacts to cover the gap via domestic and/or external commercial borrowing, consumption and/or labor income tax adjustments, and/or adjustments in government consumption and/or government transfers. Below we explicitely define $f_{in,t}$ and $f_{out,t}$, and we explain in greater detail how the mechanism of closing the fiscal gap works.

The resource windfall is managed using a delinked approach. Under this approach a scaling-up path of public investment is specified as a second-order delay function,

$$\frac{g_t^I}{g^I} = 1 + \left[1 + \exp(-k_1 t) - 2\exp(-k_2 t)\right] g_{nss}^I, \tag{A30}$$

where g_{nss}^I is the scaling-up investment target expressed as percentage deviation from the initial steady state, $k_1 > 0$ represents the speed of adjustment of public investment to the new level and $k_2 \geq k_1$ represents the degree of investment overshooting. In particular, if $k_1 = k_2 = 0$, $g_t^I = g^I \; \forall t$, i.e. public investment remains unchanged. If $k_1 \to \infty$, public investment jumps to the new steady state immediately. If $k_2 = k_1$, public investment is not overshot; while increasing values of k_2 imply increasing degrees of overshooting. Parameter k_1, k_2, and g_{nss}^I, can be chosen in a way commensurate to the economy's profile of resource revenue, absorptive capacity, resource revenue horizon and development objective, in order to make the investment scaling up sustainable from a fiscal and a more general macroeconomic point of view.

Government's flow budget constraint and fiscal gap

The government's flow budget constraint is

$$\begin{aligned}
&\tau_t^C c_t + \tau_t^L w_t L_t + t_{O,t} + \left(1 - \vartheta^K\right)\tau^K \left(r_{T,t}^K k_{T,t-1} + r_{N,t}^K k_{N,t-1}\right) \\
&+ b_t + s_t d_t + s_t d_{c,t} + s_t R^{swf} f_{t-1}^* + \mu k_{G,t-1} \\
&= p_t^G \left(g_t^C + g_t^I\right) + z_t - s_t gr_t^* + R_{t-1} b_{t-1} + s_t R_d d_{t-1} + s_t R_{dc,t-1} d_{c,t-1} + s_t f_t^*
\end{aligned} \tag{A31}$$

where gr_t^* are grants, d_t is concessional borrowing, $d_{c,t}$ is external commercial borrowing, $\mu \equiv f p_t^G \delta_G$ are user fees paid on public capital (computed as fraction f of recurrent costs), and R_d (assumed to be constant) and $R_{dc,t}$ are the gross real interest rates paid on concessional borrowing and external commercial borrowing, respectively. The latter incorporates a risk premium depending on the deviations of total external public debt to GDP ratio from its initial steady state,

$$R_{dc,t-1} = R^f + \upsilon_{dc} \exp\left[\eta_{dc}\left(\frac{d_t + d_{c,t}}{y_t} - \frac{d + d_c}{y}\right)\right], \tag{A32}$$

where R^f is a (constant) risk-free world interest rate, y_t is total GDP and υ_{dc} and η_{dc} are structural parameters. To captures distortions related to inefficiencies of revenue mobilization in low-income countries, we allow fraction $\vartheta^K \in [0,1]$ of capital tax revenue not to appear in the government budget constraint. In other words the government is unable to use these as additional sources of fiscal revenue.

The government is assumed to accept all concessional loans extended by official creditors. It is also assumed that borrowing and the amortization schedule for these loans is set exogenously. Given the path of public investment, concessional borrowing and grants, straightforward algebraic manipulation of equation (A31) allows decomposing the government's flow budget constraint into two components: (i) the fiscal gap before any policy adjustment,

$$gap_t = f_{in,t} - f_{out,t} + s_t\left(f_t^* - f_{t-1}^*\right), \tag{A33}$$

where

$$f_{in,t} = \tau_0^C c_t + \tau_0^L w_t L_t + \left(1-\vartheta^K\right)\tau^K\left(r_{T,t}^K k_{T,t-1} + r_{N,t}^K k_{N,t-1}\right) + t_{O,t} + \mu k_{G,t-1}$$
$$+ s_t a_t^* + s_t gr_t^* + s_t\left(R^{swf} - 1\right)f_{t-1}^* + s_t \Delta d_t, \tag{A34}$$

$$f_{out,t} = p_t^G g_t^I + p_t^G g_0^C + z_0 + \left(s_t R_d - 1\right)d_{t-1}$$
$$+ \left(R_{dc,t-1} - 1\right)s_t d_{c,t-1} + \left(R_{t-1} - 1\right)b_{t-1}, \tag{A35}$$

and (ii) the policy reaction to cover the gap itself,

$$gap_t = \Delta b_t + s_t \Delta d_{c,t} + \left(\tau_t^C - \tau_0^C\right)c_t + \left(\tau_t^L - \tau_0^L\right)w_t L_t - p_t^G\left(g_t^C - g_0^C\right) - \left(z_t - z_0\right), \tag{A36}$$

which entails domestic and/or external commercial borrowing, $\Delta b_t + s_t \Delta d_{c,t}$, consumption and/or labor income tax adjustments, $\left(\tau_t^C - \tau_0^C\right)c_t + \left(\tau_t^L - \tau_0^L\right)w_t L_t$, and/or adjustments in government consumption and/or government transfers, $-\,p_t^G\left(g_t^C - g_0^C\right) - \left(z_t - z_0\right)$. By combining equations (A29) and (A33), it is straightforward to see that, if $f_t^* > f_{floor}$, then $gap_t = 0$, i.e. the SWF absorbs any fiscal gap and no fiscal policy adjustments need to be made. When $f_t^* = f_{floor}$, then $gap_t > 0$ and this needs to be covered as explained in the next subsection.

Covering the fiscal gap

The split in the change in government borrowing (other than concessional borrowing) between domestic and external commercial borrowing occurs according to a given convex splitting rule,

$$\aleph \Delta b_t = \left(1 - \aleph\right)s_t \Delta d_{c,t}, \tag{A37}$$

where $\aleph \in [0,1]$ is a policy parameter. This rule accommodates also the limiting cases in which the whole change in government borrowing is due to the domestic part (if $\aleph = 0$) or the external commercial part (if $\aleph = 1$).

Debt sustainability, however, requires that eventually revenue has to increase and/or expenditures have to be cut in order to cover the entire gap. In order to determine debt stabilizing (target) values of (i) the consumption tax rate, (ii) the labor income tax rate, (iii) government consumption and (iv) government transfers, policymakers use the following four relationships:

$$\tau^C_{\text{target},t} = \tau^C_0 + \lambda_1 \frac{gap_t}{c_t}, \tag{A38}$$

$$\tau^L_{\text{target},t} = \tau^L_0 + \lambda_2 \frac{gap_t}{w_t L_t}, \tag{A39}$$

$$g^C_{\text{target},t} = g_0 + \lambda_3 \frac{gap_t}{p^G_t}, \tag{A40}$$

$$z_{\text{target},t} = z_0 + \lambda_4 gap_t, \tag{A41}$$

where $\lambda_i, i = 1,...,4$ are policy parameters and satisfy $\sum_{i=1}^4 \lambda_i = 1$. Tax rates and expenditure items are then determined according to the decision rules,

$$\tau^C_t = \min\{\tau^C_{\text{rule},t}, \tau^C_{\text{ceiling}}\}, \tag{A42}$$

$$\tau^L_t = \min\{\tau^L_{\text{rule},t}, \tau^L_{\text{ceiling}}\}, \tag{A43}$$

$$\frac{g^C_t}{g^C} = \max\left\{\frac{g^C_{\text{rule},t}}{g^C}, g^C_{\text{floor}}\right\}, \tag{A44}$$

$$\frac{z_t}{z} = \max\left\{\frac{z_{\text{rule},t}}{z}, z_{\text{floor}}\right\}, \tag{A45}$$

where τ^C_{ceiling} and τ^L_{ceiling} are ceilings on the tax rates, and g^C_{floor} and z_{floor} are floors for government consumption and transfer deviations from their initial steady-state values, while $\tau^C_{\text{rule},t}$, $\tau^L_{\text{rule},t}$, $g^C_{\text{rule},t}$, and $z_{\text{rule},t}$ are determined by the fiscal rules,

$$\tau^C_{\text{rule},t} = \tau^C_{t-1} + \zeta_1\left(\tau^C_{\text{target},t} - \tau^C_{t-1}\right) + \zeta_2\left(x_{t-1} - x\right), \qquad \zeta_1, \zeta_2 > 0, \tag{A46}$$

$$\tau^L_{\text{rule},t} = \tau^L_{t-1} + \zeta_3\left(\tau^L_{\text{target},t} - \tau^L_{t-1}\right) + \zeta_4\left(x_{t-1} - x\right), \qquad \zeta_3, \zeta_4 > 0, \tag{A47}$$

$$\frac{g^C_{\text{rule},t}}{g^C} = \frac{g^C_{t-1}}{g^C} + \zeta_5 \frac{\left(g^C_{\text{target},t} - g^C_{t-1}\right)}{g^C} - \zeta_6\left(x_{t-1} - x\right), \qquad \zeta_5, \zeta_6 > 0, \tag{A48}$$

$$\frac{z_{\text{rule},t}}{z} = \frac{z_{t-1}}{z} + \zeta_7 \frac{\left(z_{\text{target},t} - z_{t-1}\right)}{z} - \zeta_8\left(x_{t-1} - x\right), \qquad \zeta_7, \zeta_8 > 0, \tag{A49}$$

where $\zeta_i, i = 1,...,6$ are policy parameters, and $x_t \equiv \dfrac{b_t + s_t d_{c,t}}{y_t}$ is the sum of domestic and external commercial debt as a share of GDP.

Identities and market clearing conditions

After aggregating across the types of consumers, the total demand for non-traded goods is

$$d_{N,t} = \varphi p_{N,t}^{-\chi}\left(c_t + i_{N,t} + i_{T,t}\right) + \nu_t \left(\frac{p_{N,t}}{p_t^G}\right)^{-\chi} g_t, \tag{A50}$$

hence the market clearing condition for non-traded goods corresponds to

$$y_{N,t} = d_{N,t}. \tag{A51}$$

Total real GDP, y_t, is given by

$$y_t = p_{N,t} y_{N,t} + s_t y_{T,t} + y_{O,t}, \tag{A52}$$

the current account deficit, ca_t^d, reads as

$$ca_t^d = c_t + i_{N,t} + i_{T,t} + p_t^G g_t + \Theta_t^{OPT*} - y_t - s_t rm_t^* + \left(R_d - 1\right)s_t d_{t-1}$$
$$+ \left(R_{dc,t-1} - 1\right)s_t d_{c,t-1} + \left(R_{t-1}^* - 1\right)s_t b_{t-1}^* - \left(R^{swf} - 1\right)s_t f_{t-1}^*, \tag{A53}$$

and finally the balance of payment condition is

$$\frac{ca_t^d}{s_t} = gr_t^* - \Delta f_t^* + \Delta d_t + \Delta d_{c,t} + \Delta b_t^*. \tag{A54}$$

B. First-order conditions

Demand functions for tradable and non-tradable goods

$$c_{N,t}^i = \varphi\left(\frac{P_{N,t}}{P_t}\right)^{-\chi} c_t^i \qquad \forall i = OPT, ROT \tag{B1}$$

$$c_{T,t}^i = \left(1-\varphi\right)\left(\frac{P_{T,t}}{P_t}\right)^{-\chi} c_t^i \qquad \forall i = OPT, ROT \tag{B2}$$

Labour supply in the tradable and non-tradable sector

$$L_{N,t}^i = \delta\left(\frac{w_{N,t}}{w_t}\right)^{\rho} L_t^i \qquad \forall i = OPT, ROT \tag{B3}$$

$$L_{T,t}^i = \left(1-\delta\right)\left(\frac{w_{T,t}}{w_t}\right)^{\rho} L_t^i \qquad \forall i = OPT, ROT \tag{B4}$$

Optimizing households' decisions

$$\lambda_t\left(1+\tau_t^C\right) = \left(c_t^{OPT}\right)^{-\sigma} \tag{B5}$$

$$\kappa^{OPT}\left(L_t^{OPT}\right)^{\psi} = \lambda_t\left(1-\tau_t^L\right)w_t \tag{B6}$$

$$\lambda_t = \beta E_t\left(\lambda_{t+1} R_t\right) \tag{B7}$$

$$\lambda_t = \beta E_t\left[\frac{\lambda_{t+1}s_{t+1}R_t^*}{\left[s_t - \eta\left(b_t^{OPT*} - b^{OPT*}\right)\right]}\right] \tag{B8}$$

Rule-of-thumb households' decisions

$$c_t^{ROT} = \frac{\left(1-\tau_t^L\right)w_t L_t^{ROT} + s_t rm_t^* + z_t - \mu k_{G,t-1}}{\left(1+\tau_t^C\right)} \tag{B9}$$

$$L_t^{ROT} = \left(\frac{1}{\kappa^{ROT}}\frac{1-\tau_t^L}{1+\tau_t^C}\left(c_t^{ROT}\right)^{-\sigma} w_t\right)^{\frac{1}{\psi}} \tag{B10}$$

Non-tradable sector's decisions

$$w_{N,t} = \alpha_N p_{N,t}\frac{y_{N,t}}{L_{N,t}} \tag{B11}$$

$$q_{N,t} = E_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}\left(\left(1-\delta_N\right)q_{N,t+1} + \left(1-\tau^K\right)\left(1-\alpha_N\right)p_{N,t+1}\frac{y_{N,t+1}}{k_{N,t}}\right)\right] \tag{B12}$$

$$\begin{aligned}\frac{1}{q_{N,t}} = &\left[1-\frac{\kappa_N}{2}\left(\frac{i_{N,t}}{i_{N,t-1}}-1\right)^2 - \kappa_N\left(\frac{i_{N,t}}{i_{N,t-1}}-1\right)\frac{i_{N,t}}{i_{N,t-1}}\right] \\ &+ E_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}\kappa_N\frac{q_{N,t+1}}{q_{N,t}}\left(\frac{i_{N,t+1}}{i_{N,t}}-1\right)\left(\frac{i_{N,t+1}}{i_{N,t}}\right)^2\right]\end{aligned} \tag{B13}$$

Tradable sector's decisions

$$w_{T,t} = \alpha_T s_t\frac{y_{T,t}}{L_{T,t}} \tag{B14}$$

$$q_{T,t} = E_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}\left(\left(1-\delta_T\right)q_{T,t+1} + \left(1-\tau^K\right)\left(1-\alpha_T\right)s_{t+1}\frac{y_{T,t+1}}{k_{T,t}}\right)\right] \tag{B15}$$

$$\begin{aligned}\frac{1}{q_{T,t}} = &\left[1-\frac{\kappa_T}{2}\left(\frac{i_{T,t}}{i_{T,t-1}}-1\right)^2 - \kappa_T\left(\frac{i_{T,t}}{i_{T,t-1}}-1\right)\frac{i_{T,t}}{i_{T,t-1}}\right] \\ &+ E_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}\kappa_T\frac{q_{T,t+1}}{q_{T,t}}\left(\frac{i_{T,t+1}}{i_{T,t}}-1\right)\left(\frac{i_{T,t+1}}{i_{T,t}}\right)^2\right]\end{aligned} \tag{B16}$$

C. Calibration

Calibrating the model requires data on income shares of GDP, cost shares, elasticities of substitution, tax rates, debt and asset stocks, depreciation rates and the return on infrastructure. The frequency in the model is annual. Table 3 summarizes the calibration, while the rationale for the parameter choice is discussed below:

- *National accounting.* To reflect Mozambican averages in WEO/IFS data for the last decade, the share of imports in GDP is 41% and the trade deficit is 11% of GDP, which implies a share of exports of 30% of GDP. The share of government spending is 29% of GDP, 13 percent point of which is for investment. A share of private investment of 10% of GDP, together with an annual depreciation rate of 10%, and an official tax rate on the return on capital of 32% implies a distortion in revenue mobilization of around 42%. We set a share of tradables in private and public consumption of 60% to reflect the trade deficit. Since the economy is at the initial stages of substantial natural resource exploitation, the share of natural resources in total GDP is 1%.

- *Assets, debt and grants*. Stocks of assets and debt, as well, as the flow of grants, reflect 2012 figures. In line with the fact that the natural resource sector is still a small share of the economy, in the initial steady state government savings are small, i.e. 1% of GDP ($swf_{share} = 0.01$). Government domestic debt, concessional debt and grants are 9%, 4% and 5% of GDP respectively ($b_{share} = 0.09$, $d_{share} = 0.04$ and $gr_{share} = 0.05$). Private foreign debt amount to 9% of GDP ($b^*_{share} = 0.09$). In addition, the government has access to external commercial loans for 16% of GDP, i.e. $d_{c,share} = 0.16$.

Table 3. Calibration

Parameter	Value	Definition	Parameter	Value	Definition
$\exp_{share}$	0.30	Exports to GDP	ρ_{yo}	0.90	Persistence of the mining prod. shock
imp_{share}	0.41	Imports to GDP	f	0.50	User fees of public infrastructure
g^C_{share}	0.16	Government consumption to GDP	τ^L	0.05	Labor income tax rate
g^I_{share}	0.13	Government investment to GDP	τ^C	0.17	Consumption tax rate
i_{share}	0.10	Private investment to GDP	τ^K	0.32	Tax rate on the return on capital
$y_{O,share}$	0.01	Natural resources to GDP	f_{floor}	0	Lower bound for the stabilization fund
$g_{T,share}$	0.60	Share of tradables in gov. expend.	$\aleph$	1	Proportion of adj. via ext. comm. borr.
$c_{T,share}$	0.60	Share of tradables in private cons.	λ_1	1	Proportion of adj. via cons. tax
swf_{share}	0.01	Stabilization fund to GDP	λ_2	0	Prop. of fisc. adjust. via lab. inc. tax
b_{share}	0.09	Government domestic debt to GDP	λ_3	0	Prop. of fisc. adjust. via gov. cons.
b^*_{share}	0.13	Private foreign debt to GDP	λ_4	0	Prop. of fiscal adjustment via transfers
d_{share}	0.04	Concessional debt to GDP	ζ_1	0.1	Speed of adj. of the cons. tax to target
$d_{c,share}$	0.16	Gov. external comm. debt to GDP	ζ_2	0.001	Resp. of cons. tax to debt/GDP
gr_{share}	0.05	Grants to GDP	ζ_3	1	Speed of adj. of lab. inc. tax to target

$(R-1)$	0.10	Domestic net real interest rate	ζ_4	0	Resp. of lab. inc. tax to debt/GDP
$(R^{swf}-1)$	0.027	For. net real interest rate on savings	ζ_5	1	Speed of adj. of gov. spend. to target
(R_d-1)	0	Net real interest rate on conc. debt	ζ_6	0	Resp. of gov. cons. to debt/GDP
(R^f-1)	0.04	Net real risk-free rate	ζ_7	1	Speed of adj. of transfers to target
$(R_{dc,0}-1)$	0.06	Net real int. rate on ext. comm. debt	ζ_8	0	Resp. of transfers to debt/GDP
η_{dc}	0	Elasticity of sovereign risk	g^C_{floor}	$-\infty$	Floor on real government spending
α_N	0.45	Labor inc. share in non-traded sector	z_{floor}	$-\infty$	Floor on real transfers
α_T	0.60	Labor income share in traded sector	$\tau^C_{ceiling}$	$+\infty$	Ceiling on consumption tax
δ_N	0.10	Cap. deprec. rate in non-tradable sect.	$\tau^L_{ceiling}$	$+\infty$	Ceiling on labour income tax
δ_T	0.10	Cap. depreciation rate in traded sector	ν	0.6	Home bias of government purchases
ρ_{y_T}	0.10	Learning by doing in the traded sector	ν_g	0.5	Home bias for add. government spending
ρ_{z_T}	0.10	Persistence in TFP in traded sector	α_G	0.25	Elast. of output to public capital
κ_N	25	Invest. adj. cost in the non-traded sect.	δ_G	0.07	Depreciation rate of public capital
κ_T	25	Invest. adj. cost in the traded sector	$\bar{\varepsilon}$	0.60	Steady-state efficiency of pub invest.
ψ	10	Inv. of the Frisch elast. of labor supply	g^I_{nss}	0.50	Planned long-term scaling up
σ	2	Inv. of the inter-temp. elast. of subst.	k_1	-	Speed of scaling up plan
ρ	1	Elast. of subst. betw. types of labor	k_2	-	Degree of overshooting
ω	0.60	Measure of optimizers in the economy	ρ_δ	0.80	Pers. of depr. rate of public capital
χ	0.44	Elast. of subst. betw. traded/non-traded	ϕ	1	Severity of public capital depreciation
η	1	Elasticity of portfolio adiustment costs	ς_ε	20	Severity of absorp. capacity constraints
τ^O	0.85	Royalty tax rate on natural resources	$\bar{\gamma}^{GI}$	0.50	Thresholds of absorp. capac. constraints
ρ_{po}	1	Persist. of the commodity price shock			

- *Interest rates.* The coefficient of risk aversion, σ, set equal to 2 implies an inter-temporal elasticity of substitution of 0.50 as common in the literature. We set the subjective discount rate, ρ, such that the real net interest rate on domestic debt, $(R-1)$, is 10%. Since the real interest rate on domestic debt and the real return on private capital are the same at the steady state, this is consistent with the estimated return on private capital in Dalgaard and Hansen (2005), but also with the stylized fact that domestic debt in low- and middle-income countries is usually more costly than external commercial debt.

In fact, we fix the real risk-free interest rate, (R^f-1), at 4%, in line with average historical real returns on US T-bill rates, and parameter υ_{dc} such that the real interest rate on external commercial debt, $(R_{dc}-1)$, is 6%, in line with average IMF-World Bank Debt Sustainability Analyses (IMF-WB DSAs). In addition, in IMF-WB DSAs, on average the real interest rate paid on concessional loans, (R_d-1), equal to 0%. No additional risk-premium, $\eta_{dc}=0$, is assumed in the baseline calibration. Parameter u is chosen in order $R=R^*$ at the steady state, which is required by equations (A.7) and (A.8). Finally, based on average real returns of the Norwegian Government Pension Fund from

1997 to 2011 (Gros and Mayer, 2012), the annual return on international financial assets is set equal to 2.7%.

- *Private production*. In line with the evidence on Sub-Saharan Africa surveyed in Buffie et al. (2012), we set the labor shares of income in the non-traded and in the traded as $\alpha_N = 0.45$ and $\alpha_T = 0.60$, respectively. In both sectors private capital is assumed to depreciate at an annual rate of 10% ($\delta_N = \delta_T = 0.10$). Following Berg et al. (2012) we assume a minor degree of learning-by-doing externality in the traded sector ($\rho_{Y_T} = \rho_{z_T} = 0.10$). Finally, following the calibration of Berg et al. (2010), investment adjustment costs are set to $\kappa_N = \kappa_T = 25$.

- *Households preferences.* Following Berg et al. (2012) a low Frisch labor elasticity of 0.10 ($\psi = 10$) is assumed, in line with estimates of rural Malawi (Goldberg, 2011); the labor mobility parameter is set equal to unity (Horvarth, 2000), $\rho = 1$, and the elasticity of substitution between traded and non-traded goods is set equal to $\chi = 0.44$ following Stockman and Tesar (1995). To capture the fact that the capital account has a low degree of openness, i.e. the private sector has limited access to international capital markets, we set $\eta = 1$ as in Buffie et al. (2012). We set $\omega = 0.60$, which imply that 40% of consumers are entirely not savers.

- *Mining*. Resource production shocks are assumed to be rather persistent, so we set $\rho_{yo} = 0.90$. This parameter is not relevant when a defined exogenous path for resource production is assumed as we do in the simulations below. Given that Hamilton (2009) finds that oil prices follow a random walk with drift, and typically LNG is priced taking oil parity as a benchmark, we set $\rho_{po} = 1$. Finally the royalty tax rate, τ^O , is set such that the ratio of natural resource revenue to total revenue at the peak of natural resource production is substantial, around 40% of total revenues. In this case $\tau^O = 0.85$.

- *Tax rates*. The steady-state taxes on consumption, and capital are $\tau^C = 0.17$, and $\tau^K = 0.32$, respectively. We set the labor income tax rate at $\tau^L = 0.05$, lower than the official tax rates given that the model, featuring a representative agent, does not explicitely capture the fact many households do not pay income taxes in LICs. This combination of tax rates and the implied inefficiency in revenue mobilization imply a non-resource revenue of slightly above 20 percent of GDP at the initial steady state, which is broadly in line with Mozambican data.

- *Fiscal rules*. We impose a non-negativity constraint for the stabilization fund by setting $f_{floor} = 0$. In our baseline calibration fiscal instruments do not have floors or ceilings.

This translates in setting $g^C_{floor} = z_{floor} = -\infty$ and $\tau^C_{ceiling} = \tau^L_{ceiling} = +\infty$. The baseline calibration also implies that the whole fiscal adjustment takes place through changes in external commercial borrowing and consumption taxes. This is achieved by setting $\aleph = \lambda_1 = 1$, $\lambda_2 = \lambda_3 = \lambda_4 = 0$, $\zeta_3 = \zeta_5 = \zeta_7 = 1$, $\zeta_4 = \zeta_6 = \zeta_8 = 0$. In addition, in order to make tax changes smooth, we choose a small adjustment of the consumption tax rate to target of $\zeta_1 = 0.1$ and a very low responsiveness of the consumption tax rate to the debt-to-GDP ratio ($\zeta_2 = 0.001$).

- *Public investment*. Public investment parameters broady follow the values chosen by Berg et. al (2012) for the Angola and CEMAC region applications. In particular public investment efficiency is 60%, ($\bar{\varepsilon} = 0.6$), which is somewhat above the average LIC estimates of Gupta et al. (2011), to capture the fact that most infrastructure projects in Mozambique are planned to be executed by leading international companies. The depreciation rate for public capital is 7% per year ($\delta^G = 0.07$), somewhat lower than the depreciation rate of private capital given that the latter – in a model abstracting from durable goods – captures the depreciation of goods caracterized by a stronger degree of economic obsolescence. The home bias for public spending, ν, and for spending above the level of the initial steady state, ν^g, are 0.6 and 0.5, respectively. This captures the fact that, while at the steady state a bigger portion of public spending goes to the wages of public employees, in a public investment scaling up, much of the investment goods are imported in LICs. The elasticity of output to public capital is $\alpha^G = 0.25$, which implies a marginal net return of public capital of 15% at the initial steady state. We normalize the severity of public capital depreciation to unity ($\phi = 1$) and make the depreciation rate of public capital a persistent process ($\rho_\delta = 0.8$). We assume that absorptive capacity constraints starts binding when public investment positively deviates beyond 50% from its initial steady state ($\bar{\gamma}^{GI} = 0.50$), close to the estimates of Prichett (2000) for sub-Saharan Africa and make of absorptive capacity constraints severe ($\varsigma_\varepsilon = 20$) to an extent that average investment efficiency approximately halves to around 30% if public investment were to spike to around 200% from its initial steady state. For illustrative purposes, in the delinked approach, we set the the planned long-term scaling up of investment such that public investment at the new steady state is 50% higher than at the initial steady state ($g^I_{nss} = 0.50$). The speed of the scaling-up plan, k_1, and the degree of overshooting, k_2, are chosen in different ways for alternative experiments and are reported in the following sections.