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REPUBLIC OF MOZAMBIQUE

SELECTED ISSUES

June 2019

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Approved By
African Department

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MOZAMBIQUE'S NATURAL GAS RESOURCES: TRADEOFFS AND OPPORTUNITIES[1]

Mozambique is poised to become a major exporter of liquified natural gas (LNG), with significant impact on transforming its economy. If appropriate policies are put in place, LNG may generate long lasting gains, potentially lifting millions out of poverty. This paper addresses the challenges of transforming natural gas resource wealth underground into financial flows to support sustained development while, at the same time, avoiding Dutch disease and boom-bust cycles that are common to many natural resource rich economies. It applies the Debt, Investment, Growth and Natural Resources (DIGNAR) model to analyze the macroeconomic effects of alternative scenarios of scaling-up public investment in a volatile and exhaustible resource revenue environment to meet the country's development needs. The model results indicate that prudent and gradual investment scaling-up is preferable to aggressive, front-loaded investments given, inter alia, absorptive capacity constraints and private sector crowding-out effects. It also shows that external savings—perhaps put in a sovereign wealth fund—would mitigate Dutch disease effects and serve as much needed fiscal buffer.

A. Background

1. Significant natural gas resources were discovered in Mozambique in 2010. Around 150 trillion cubic feet (Tcf) of proven natural gas reserves were found in two adjacent blocks, Area 1 and Area 4, in the offshore Rovuma Basin off Mozambique's northern Cabo Delgado province (Figure 1). With these discoveries Mozambique is the third largest holder of natural gas reserves in Africa (after Nigeria and Algeria) and twelfth globally.[2]

2. Natural gas will be a significant source of foreign exchange for Mozambique. Large foreign exchange proceeds would come from natural gas exports and/or increased domestic consumption of natural gas in substitution for imported sources of energy. However, exports and domestic consumption of natural gas would require setting up a large network of pipelines for delivery. Alternatively, natural gas can be exported over long distances in liquid form as LNG (Box 1).

3. Mozambique is in an ideal location for LNG trade, especially in relation to the fastest growing consumption markets. Natural gas consumption is expected to continue to grow strongly over the coming 20 years, backed by demand for industrial production and power generation (BP Energy Outlook, 2018). Currently, the bulk of LNG exports are destined for the Asian market, with Japan and China being the largest importers, and Qatar and Australia being the largest exporters (Figure 2). In 2018, global trade in LNG increased by 3.2 billion cubic feet per day (Bcf/d) to 41.3 Bcf/d, an 8 percent increase from the previous year, backed by strong demand growth in China, following government policies to promote coal-to-natural gas switching.

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[1] Prepared by Ari Aisen, Naly Carvalho, Moataz El Said, and Edson Manguinhane (all AFR).

[2] As of January 1, 2017, global natural gas reserves were estimated at 6,923 Tcf, with Russia, Iran, and Qatar accounting for around 50 percent of the total (US EIA).

4. Developing Mozambique's natural gas infrastructure will take time and require large investments. This process includes a drilling stage (upstream process) to recover raw gas from underground, and the construction of liquification plants (trains). The latter takes around 4-5 years to build and involves large investments. Reaching a final investment decision (FID) on whether to develop a project often requires securing long-term sales and purchase agreements (SPAs) that ensure that project revenues are enough to meet project financing obligations. In the case of Mozambique, it is estimated that the five trains that are being developed will require total investments of around US$55 billion (the equivalent to four-times Mozambique's 2018 GDP).

5. Considerable progress has taken place toward building Mozambique's liquification capacity. The five trains that are being developed will have a total production capacity of around 30 million tons per annum (MTPA) (2.4 Tcf)—equivalent to 17 percent of total 2017 LNG trade or 7.5 percent of projected LNG trade by 2026 (Figure 3). Initial production of LNG is expected in late 2023 and for the five trains to reach full capacity by 2026. These trains are linked to the following fields:

- **Offshore Area 1 Golfinho/Atum gas field**: This project is led by Anadarko Petroleum Corporation (Anadarko) and is managed by its Mozambique subsidiary and partners in Area 1.[3] The project involves the development of two onshore trains with a liquification capacity of 6.44 MTPA per train, with total investment estimated at US$22 billion. An FID for the project is expected by mid-2019 and production of LNG from the first train is expected by end-2024, followed by production from the second train by mid-2025. So far, SPAs that have been secured by Anadarko amount to 9.5 MTPA (Reuters; EIM LNG Intelligence Daily; and company statements).

- **Area 4 Coral South field**: This project is led by Eni and consists of developing an offshore floating train with a liquification capacity of 3.4 MTPA.[4] The FID was reached in June 2017, with total investment estimated at around US$8 billion. Production of LNG is expected by late 2023, with the entire LNG production sold to BP over 20 years. (Global Energy Research, February 2019).

- **Area 4 Mamba field**: This project is jointly led by ExxonMobil and Eni and involves the development of two onshore trains with a liquification capacity of 7.6 MTPA per train.[5] An FID for the project is planned by mid-2019, with total investment estimated at around US$25 billion. Production of LNG from the first train is expected by August 2024, followed by production from the second train by mid-2025. Area 4 co-venture participants have secured LNG sale commitments from affiliated buyer entities of the partners.

The onshore liquefication trains will be in the Afungi LNG park in Cabo Delgado province. Anadarko and Eni are jointly developing the park. The park is also expected to host additional trains; future

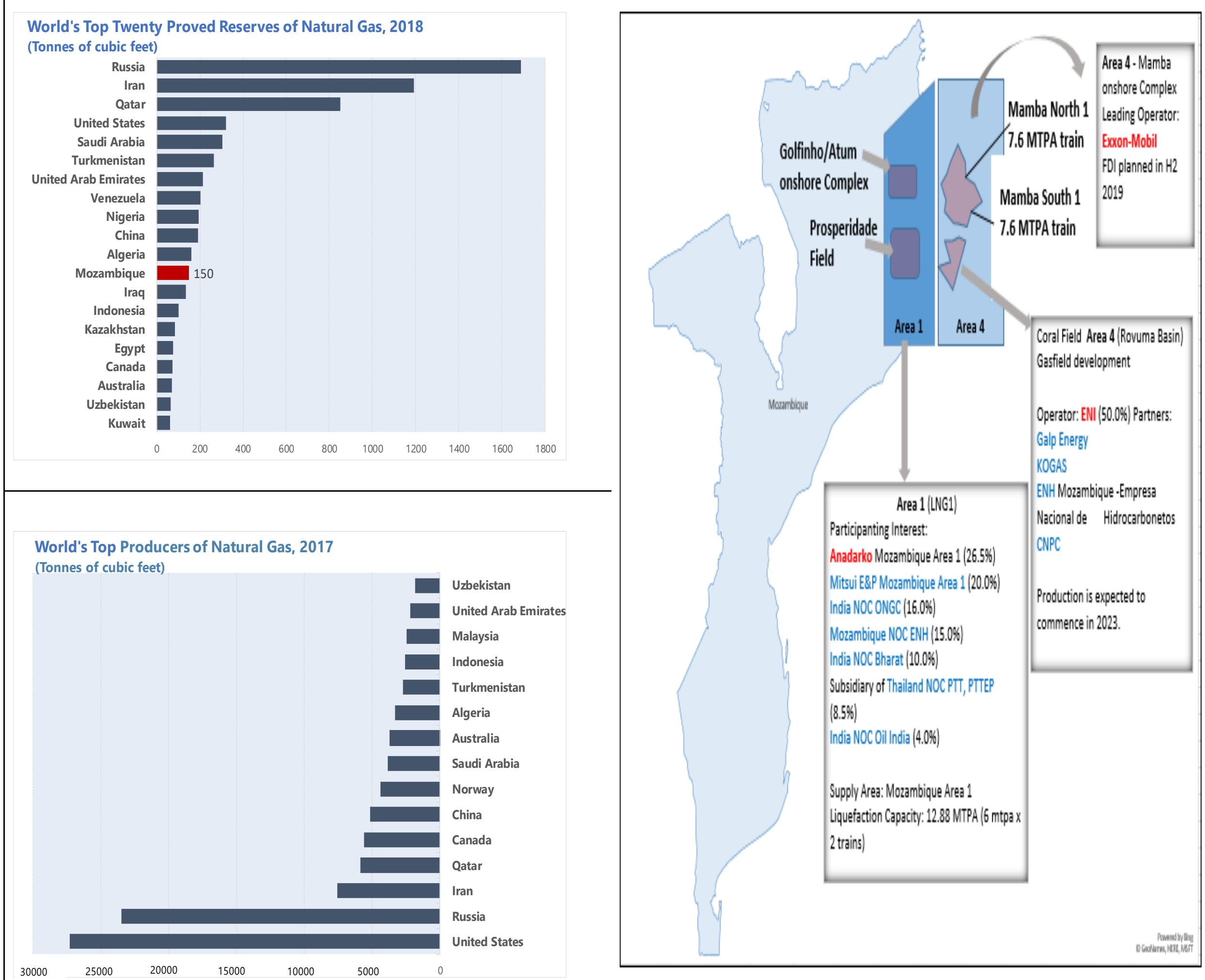
[3] Co-ventures include Anadarko (26.5 percent), Mozambique's state-owned energy company ENH (15 percent), Mitsui E&P (20 percent), ONGC Videsh Ltd. (16 percent), India Bharat Petroleum (10 percent), Thailand PTTEP (8.5 percent), and Oil India limited (4 percent).

[4] Co-ventures are ExxonMobil (25 percent), Eni (25 percent), China National Petroleum Corporation (CNPC) (20 percent), ENH (10 percent), South Korean public national gas company KOGAS (10 percent), and Portuguese group Galp (10 percent).

[5] Eni will lead the construction and operation of the upstream facilities, while ExxonMobil will lead the midstream natural gas liquefication.

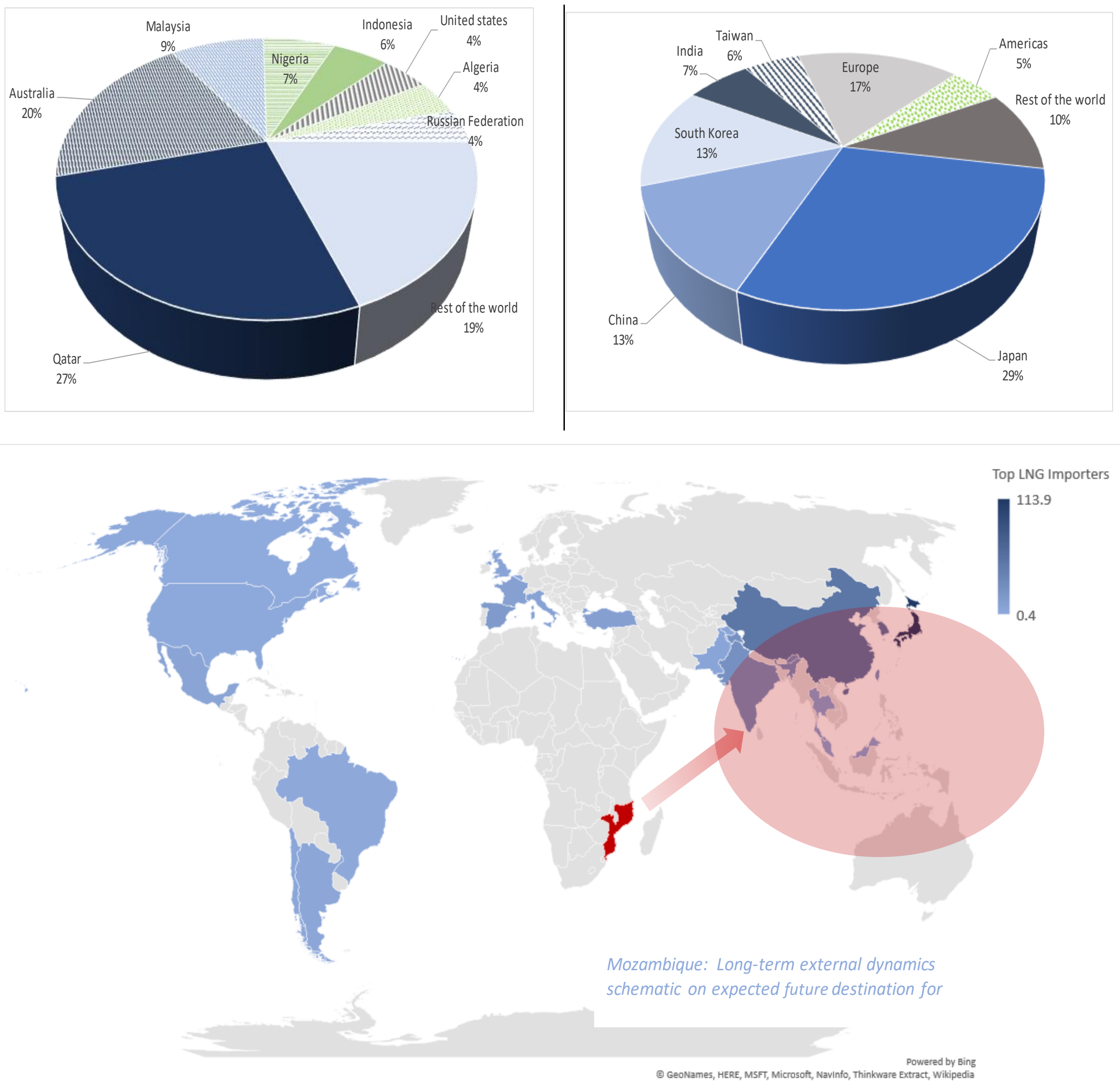
investments have the potential of adding another 27 MTPA by 2032, with 12 MTPA from Area 1 (Prosperidade field) and 15.2 MTPA from the overlapping fields between Area 1 and Area 4.

Figure 1. Global Natural Gas Reserves, Producers, and Mozambique Production Areas



Sources: US Energy Information Administration; companies' statements; and IMF staff schematic, not drawn to scale.

Figure 2. LNG Exporting and Importing Countries, 2017



Source: US Energy Information Administration and IMF Staff Schematic (illustration, not drawn to scale).

Box 1. Liquified Natural Gas 101 (LNG)

Natural gas can be exported over long distances in liquid form as LNG. To liquefy natural gas, it must be cooled to -160 degrees Celsius (about -260° Fahrenheit). The liquification plant, known as train, involves a process consisting of a progression of connected steps where the raw gas is purified first, then cooled to the required temperature. During the process, the volume of natural gas in its liquid state is compressed (about 600 times smaller than its volume in its gaseous state), which facilitates its shipping and storage.

The liquefication process makes it possible to transport natural gas to places when a pipeline infrastructure is not available and/or feasible. Markets that are too far away from producing regions have access to natural gas because of LNG. However, this requires (i) special ships equipped with insulated and pressurized tanks to transport the LNG to its destination; and (ii) at the receiving end, importing countries need to be equipped with terminals to regasify (return LNG to its gaseous state) where it is transported by a pipeline to distribution companies, industrial consumers, and power plants.

Source: US Energy Information Administration.

B. Macroeconomic Impact of Natural Gas Production

6. A Fiscal Analysis of Resource Industries (FARI) methodology is used to quantify the macroeconomic impact of natural gas development on the economy.[6] The FARI model is particularly useful for the case of Mozambique because the natural gas resources are concentrated around a few large-scale projects. Relevant information at the project level is aggregated in a consistent framework that can be easily integrated into Mozambique's macroeconomic framework to arrive at resource revenues as well as production value added and exports (Figure 3).

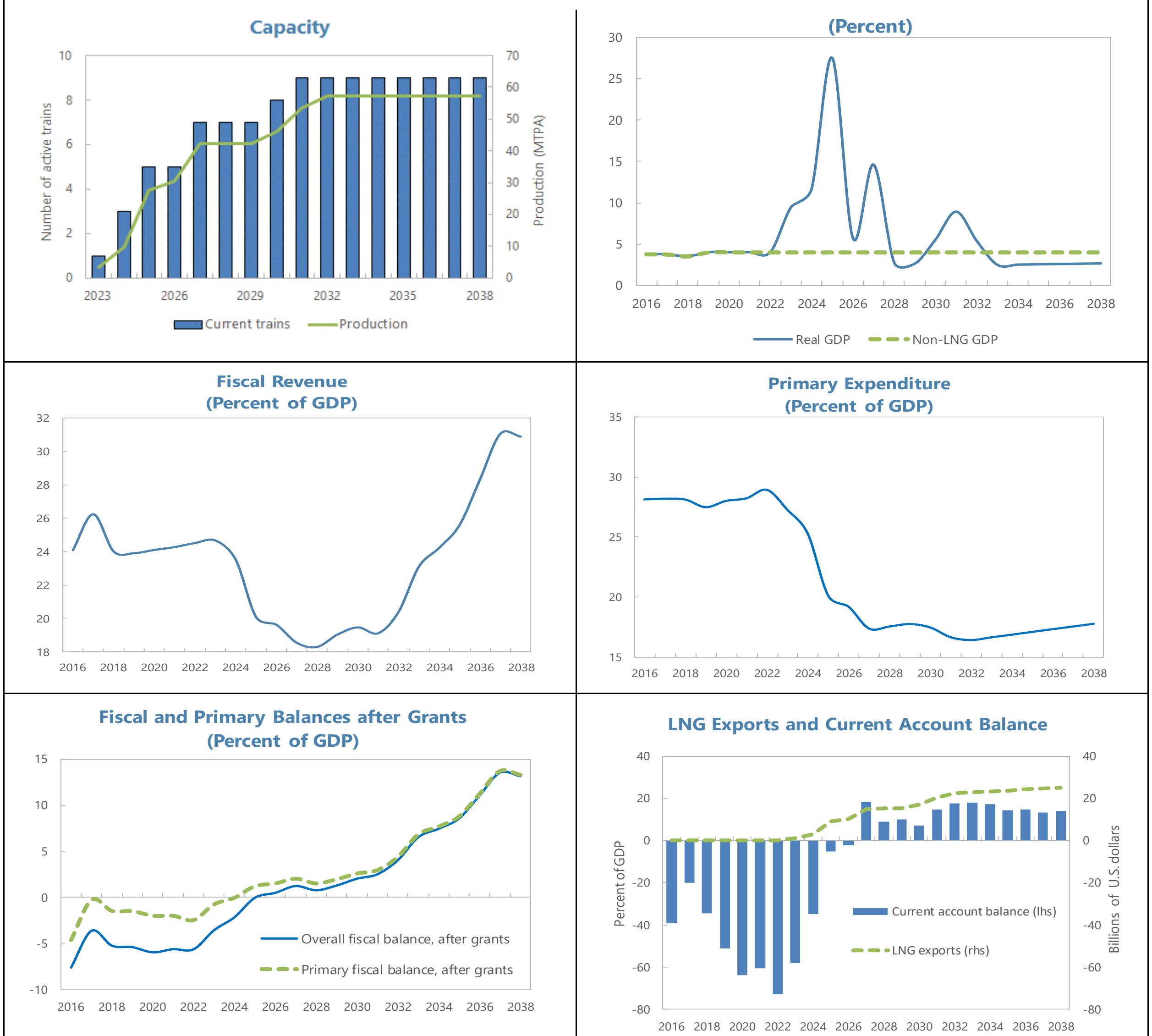
- **Real GDP growth** is projected to increase in 2023-24 in line with the onset of production from the first LNG plants (trains) and related exports. Other economic activity (non-LNG) is conservatively assumed to continue to grow at a steady rate of 4 percent per year over the long-term.

- **Fiscal**. As fiscal revenue from LNG production starts to flow in by 2023, the primary fiscal balance would improve and turn into surplus reaching around 13¼ percent of GDP by 2038. Underlying the path of improvement of the primary fiscal balance is the assumption that (i) the recovery of LNG development costs would take place over the initial four-to-six years of production, after which LNG related fiscal revenue would pick up significantly and account for almost half of total fiscal revenue, and (ii) all LNG fiscal revenue would be saved.

[6] FARI is an Excel-based model that builds up from the project-level estimates of key macro indicators; including real GDP, fiscal revenue, and exports. A technical exposition of the FARI modeling is available in IMF (2016).

- **External sector**. As LNG exports pick up in line with the production of LNG, the current account deficits would turn into surpluses by 2027.

Figure 3. Mozambique Selected Macroeconomic Indicators



Sources: Mozambican authorities and IMF staff estimates and projections.

C. The DIGNAR Model and Alternative Public Investment Approaches

7. This paper employs the DIGNAR model to analyze the fiscal and macroeconomic implications of savings / investment scaling up under different fiscal rule scenarios. This model provides a way to determine paths for the non-resource fiscal variables that are sustainable in the long run, using a macroeconomic framework that links fiscal variables, investment, growth and the real exchange rate. For a given investment scaling up path and envelope of resource revenues, the framework assesses the long-term sustainability of the fiscal path based on the magnitude of fiscal adjustments in current government spending or tax rates required to ensure debt sustainability.

8. The DIGNAR model consists of three production sectors, two types of households and the public sector. The production sectors consist of an exogenous LNG production sector and of firms that produce tradeables and non-tradeables goods through a Cobb-Douglas production function combining private and public capital and labor. The consumption side comprises optimizing and non-optimizing households, that is, includes those households that use financial markets to smooth consumption (optimizing households) and those without access or do not use financial markets to smooth consumption (non-optimizing households). In the public sector, the government raises taxes from the private sector, including on the LNG sector, to finance recurrent expenditures, investments on infrastructures and to service debt.

9. There are two main public investment approaches, namely: Spend-As-You-Go (SAYG) and Delinked. The choice of approach will affect how LNG price shocks will affect in turn macroeconomic performance.

- **Under the SAYG rule**, LNG fiscal revenues in each period are used to fund public infrastructure investment, keeping recurrent spending fixed. This approach therefore does not allow an accumulation of resources in a stabilization fund, so the initial endowment of the stabilization fund, if there is one, remains at its initial level and taxes adjust endogenously to keep debt on a sustainable trajectory. The SAYG approach is thus highly procyclical, with the dynamics of public investment and other macroeconomic variables following the dynamics of LNG fiscal revenues.

- **Under the Delinked approach**, public investment is scaled up gradually and its path is determined exogenously, that is, it is delinked from LNG revenues. Public investment is financed by a combination of LNG fiscal revenues, debt issuance and non-LNG fiscal revenues while allowing the buildup of savings in a stabilization fund. A fiscal surplus (deficit) would lead to an accumulation (reduction) of resources in the stabilization fund and, when there is a revenue shortfall, the stabilization fund would be drawn down to maintain investment commensurate with the planned path. A gradual scaling up of investment would give the authorities time to improve absorptive capacity and public investment efficiency and build fiscal buffers to prevent a disruption to public investment in the case of a negative LNG price shock.

D. LNG Production and Price Scenarios

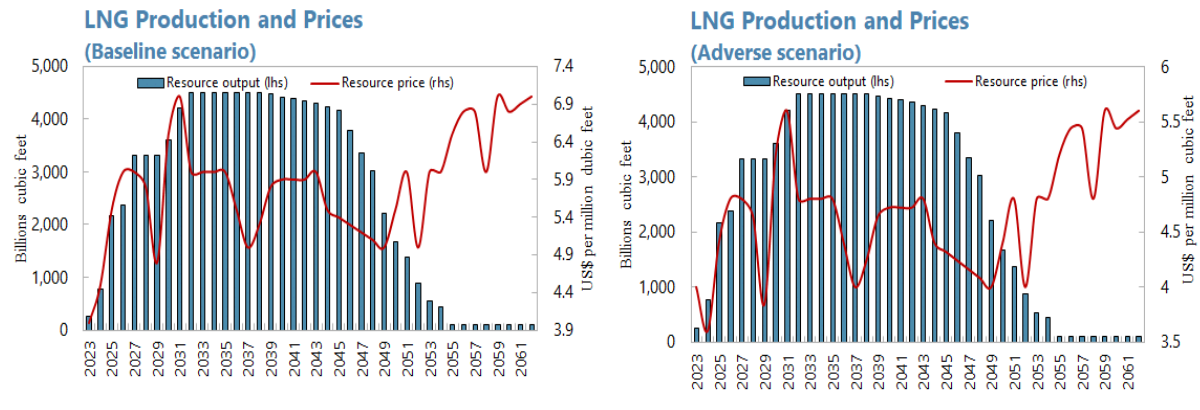
10. LNG production, prices and revenues in the baseline and adverse scenarios are shown in Figure 4:

- **LNG Production** follows the FARI model as discussed above. LNG production is assumed to start in 2023 and peak in 2032 based on production from a total of ten LNG trains.

- **LNG prices** under the baseline scenario are generated by random simulations ranging between US$2 to US$9 per million cubic feet (MCF), falling within the price range observed over the last 20 years. The idea is to capture volatility of LNG prices that is common in all commodity markets. In addition, we assume an adverse scenario under which a 20 percent negative LNG price shock is applied to the baseline scenario prices.[7]

[7] This choice was based on the observation that in the last 45 years there were 16 negative variations of LNG prices (36% of total observations) of which 11 (69% of total negative variations) were up to 20 percent.

Figure 4. LNG Production and Price Scenarios (2023-2063)



Sources**:** Mozambican authorities and IMF staff calculations.

E. Results

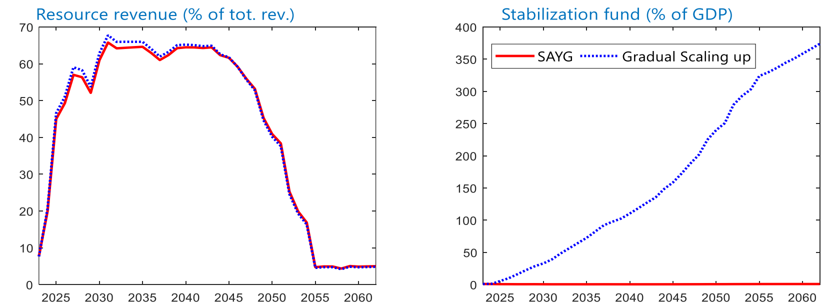
11. Figures 5 through 9 show the impact of the SAYG and Delinked approaches on macroeconomic performance under the baseline and adverse scenarios using calibrated parameters for Mozambique (Appendix).

12. A stabilization fund allows for the accumulation of buffers that can be used in the event of a drop in LNG prices. Figure 5 shows that, overtime, LNG production will decrease, and LNG prices can be volatile and lower than expected, leading to volatile LNG fiscal revenues which, in turn, would generate macroeconomic volatility. The SAYG approach is thus more susceptible to macroeconomic volatility, as no savings are accumulated, while under the Delinked approach a gradual scaling up of investment would allow for the accumulation of fiscal buffers through savings in a stabilization fund.

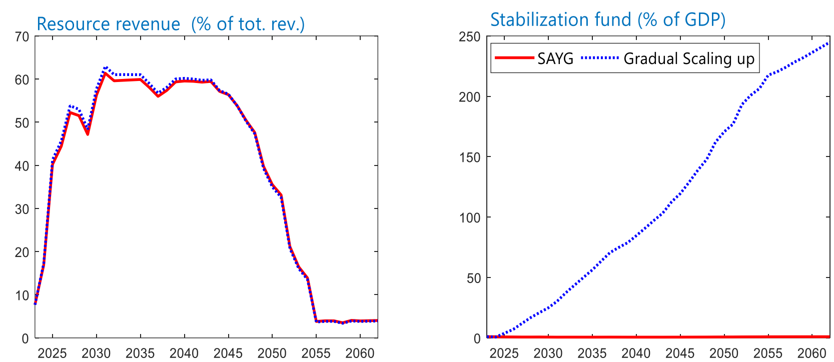
13. Excessively quick public investment scaling up would lead to investment inefficiencies. Under SAYG, public investment follows a volatile trend as it is linked to LNG revenues. Figure 6 shows that the aggressive investment scaling up under SAYG leads to a huge decline in investment efficiency, relative to the Delinked approach of gradual scaling up, mainly due to absorptive capacity constraints (lack of planning and coordination, and lower capital budget execution ratios). Under an adverse scenario, public investment efficiency improves in relative terms under SAYG, but inefficiencies remain higher than in the Delinked approach. In addition, Figure 6 shows that in the event of a negative price shock, the government would be able to maintain the same public investment path as under the gradual scaling up because this path is delinked from LNG revenues. Conversely, under SAYG, the government would be forced to implement public investment cuts as LNG revenues decline. In addition, since there are no accumulated savings under SAYG, the government must resort to additional taxes and/or debt financing to satisfy its budget constraint.

Figure 5. Resource Revenues and Stabilization Fund

A. Baseline Scenario



B. Adverse Scenario



Source: IMF staff calculations.

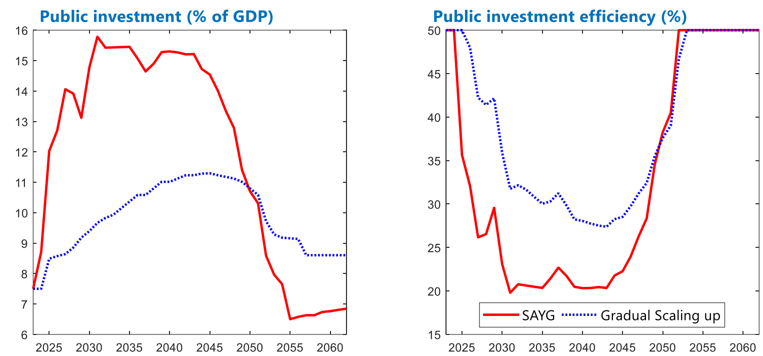
14. Gradual scaling up allows private investment, private consumption and non-LNG output to follow a more stable path. According to the model, LNG revenues lead to other taxes to be lowered which, in turn, stimulate private investment, private consumption and non-LNG output. In addition, higher LNG revenues and a higher GDP (taxation base) result in lower tax rates that are needed to satisfy the budget constraint (Figure 7). Over the medium term, lower tax rates stimulate private consumption, private investment and non-LNG output. Under SAYG, however, the tax rate is initially lower, but this is reversed over the long term, as LNG revenues decline, other taxes need to increase to satisfy the budget constraint. As a result, private investment, private consumption and non-LNG output become higher under the Delinked approach over the long term.

15. LNG production and exports will lead to real exchange rate appreciation (Figure 8). However, this is more pronounced under SAYG because all foreign exchange proceeds from LNG exports are immediately channeled to the economy. Under the Delinked approach, accumulation of resources in a stabilization fund mitigates the Dutch disease effects, by containing to some extent real exchange rate appreciation pressures.

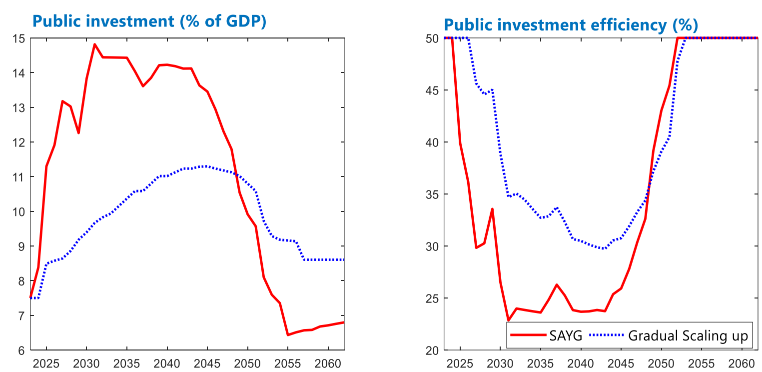
16. LNG fiscal revenues can contribute to a more sustainable debt path (Figure 9). As LNG fiscal revenues increase, the government needs to resort less to debt accumulation, leading to a decline of public debt as a share of GDP over the medium term. However, in the long-term, due to decreasing LNG fiscal revenues, public debt-to-GDP ratios would tend to increase as additional borrowing would be required. Under the Delinked approach, in both the baseline and adverse scenarios, debt levels are lower than under the SAYG approach, and the government's ability to service its debt obligations is relatively high due to accumulated savings.

Figure 6. Public Investment and Investment Efficiency

A. Baseline Scenario



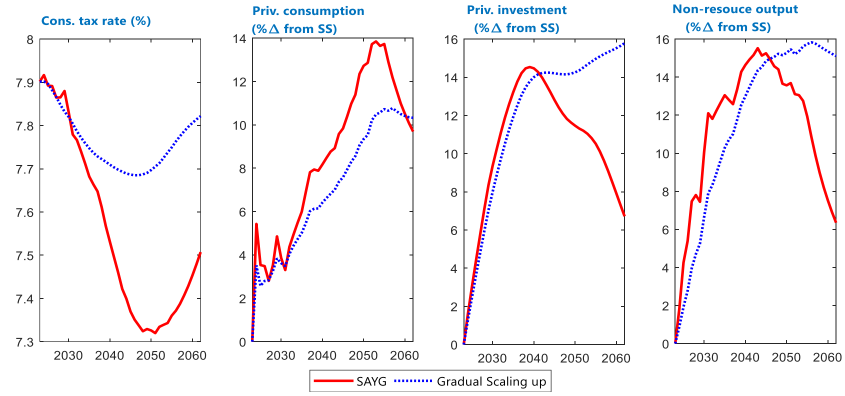
B. Adverse Scenario



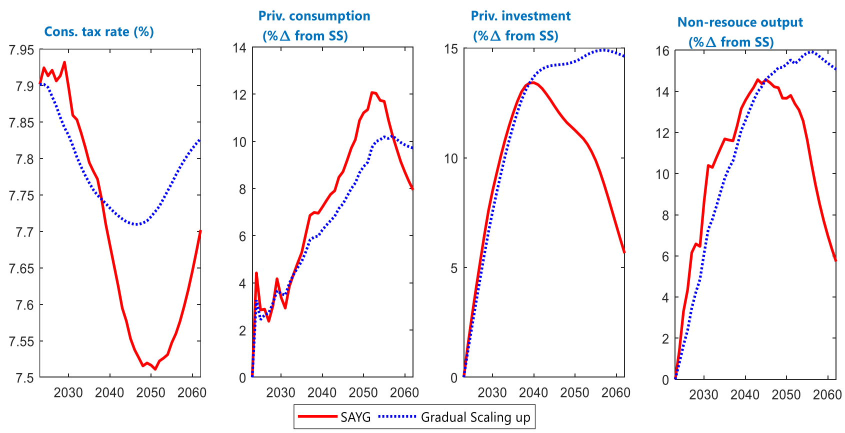
Source: IMF staff calculations.

Figure 7. Tax Rate, Private Consumption, Investment, and Non-Resource Output

A. Baseline Scenario



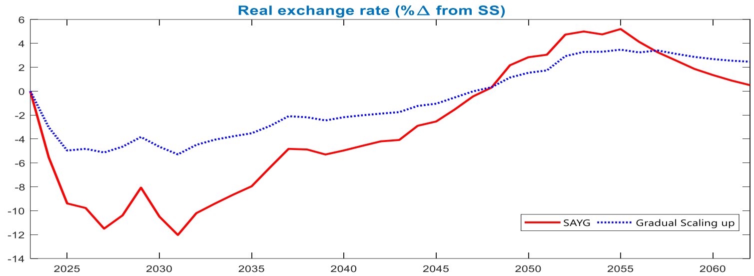
B. Adverse Scenario



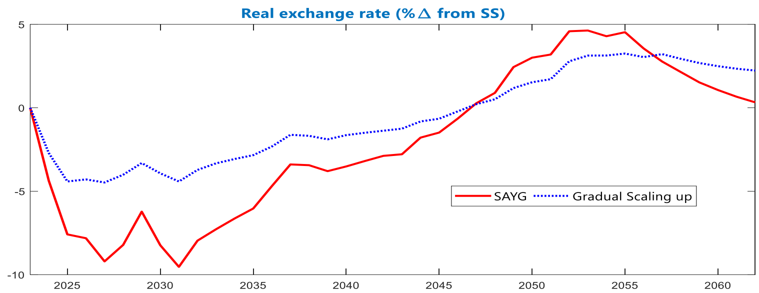
Source: IMF staff calculations.

Figure 8. Real Exchange Rate

A. Baseline Scenario



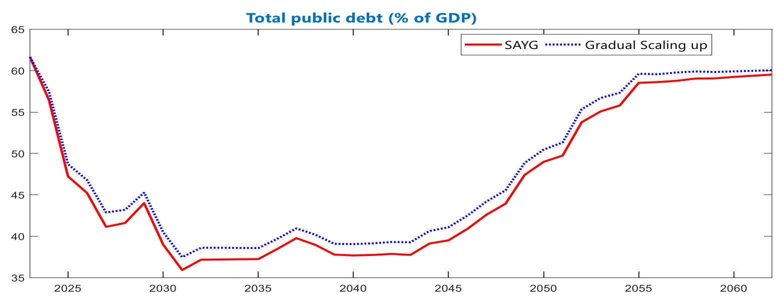
B. Adverse Scenario



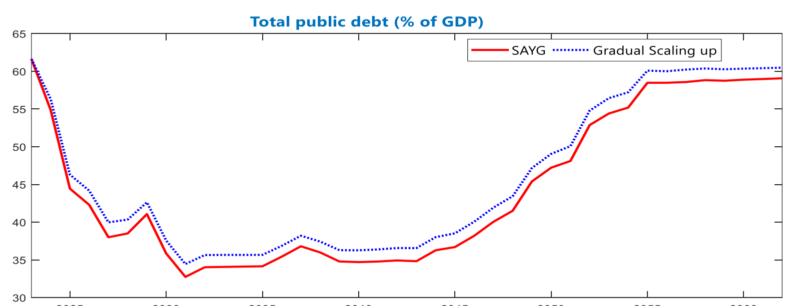
Source: IMF staff calculations.

Figure 9. Total Public Debt

A. Baseline Scenario



B. Adverse Scenario



Source: IMF staff calculations.

F. Main Findings

17. Mozambique is poised to become one of the world's largest LNG exporters over the medium term. LNG exports will generate significant fiscal revenues that the government can use to address infrastructure gaps and other social needs, fostering economic development and significantly reducing poverty. However, volatility in LNG fiscal revenues and absorptive capacity constraints create challenges to macroeconomic management, requiring the government to find the right balance between public investment, investment efficiency and macroeconomic stability.

18. The DIGNAR model offers an assessment of alternative options for scaling up of public investment. It shows that gradually scaling up investment due to higher LNG fiscal revenues would give Mozambique time to improve absorptive capacity and public investment efficiency while building fiscal buffers to prevent disruptions to investment plans when a negative LNG price shock occurs (accumulation of savings in an actual or virtual stabilization fund would prevent the need for sizable investment cuts). Moreover, gradually scaling up investment due to higher LNG fiscal revenues would contain macroeconomic volatility, including to output, and real exchange rate appreciation pressures. It would therefore be more conducive to private sector led economic diversification.

Appendix I. Calibration: Parameters and Assumptions

1. To run the simulations a set of assumptions and parameters were defined which include the national accounting, fiscal policy, interest rates, structural parameters, natural resources and, public investment. The summary of the calibration parameters is presented on Table 1.

Table 1. Mozambique: Calibrated Parameters

Sector	Indicators	Parameters
National Accounts	Long-run GDP growth rate (in percent)	6.00
	Exports/GDP*100 (in percent)	33.00
	Imports/GDP*100 (in percent)	65.00
	Government consumption/GDP*100 (in percent)	21.00
	Government investment expenditures/GDP*100 (in percent)	7.50
	Private investment/GDP*100 (in percent)	17.00
	Mining value added (natural resource production)/GDP*100 (in percent)	3.00
	Government wealth fund/GDP*100 (in percent)' (external savings)	1.00
	Share of tradables in government expenditures (in percent)	60.00
	Share of tradables in private consumption (in percent)	60.00
	Government domestic debt / GDP*100 (in percent)	8.81
	Private foreign debt/GDP*100 (in percent)	49.18
	Concessional debt/GDP*100 (in percent)	4.71
	Government external commercial debt/GDP*100 (in percent)	48.13
	Grants/GDP*100 (in percent)	5.09
Interest rates	Annualized domestic net real interest rate	10.00
	Annualized foreign net real interest rate earned by the stabilization fund	2.70
	Annualized net real interest rate paid on concessional debt	0.00
	Annualized net real risk-free rate	2.40
	Annualized net real interest rate paid on government external commercial debt	6.00
Structural parameters	Labor income share in non-traded sector (in percent)	45.00
	Labor income share in traded sector (in percent)	60.00
	Elasticity of output wrt public capital	0.25
	Capital depreciation rate in non-tradable sector (in percent)	10.00
	Capital depreciation rate in traded sector (in percent)	10.00
	Depreciation rate of public capital (in percent)	7.00
	Learning by doing externality in the traded sector	0.10
	Persistence in TFP in traded sector	0.10
	Investment adjustment cost parameter in the non-traded sector	25.00
	Investment adjustment cost parameter in the traded sector	25.00
	Steady-state efficiency of public investment (share of investment turned into actual capital) (in percent)	50.00
	Inverse of the Frisch elasticity of labor supply for optimizers	10.00
	Inverse of the Frisch elasticity of labor supply for rule of thumb consumers	10.00
	Inverse of the intertemporal elasticity of consumption	2.00
	Elasticity of substitution between the two types of labor (in tradables and nontradables)	1.00
	Measure of optimizers in the economy in percent (non-credit-constrained households)	0.60
	Elasticity of substitution between traded and non-traded goods	0.44
	Home bias for additional government spending	0.50
	Elasticity of portfolio adiustment costs	0.00
Natural resource sector	Royalty tax rate on natural resources (in percent)	20.00
Fiscal policy	User fees of public infrastructure (in percent of recurrent costs)	50.00
	Labor income tax rate	2.51
	Consumption tax rate	7.90
	Tax rate on the return on capital	5.86
	Elasticity of sovereign risk	0.00
Public investment	Severity of public capital depreciation when not maintained	1.00
	Severity of absorptive capacity constraints	20.00
	Thresholds of investment scaling up beyond which absorptive capacity constraints start binding (in percent)	50.00
	Persistence of efficiency of public investment	0.80
	Floor for the sovereign wealth fund (in percent of GDP)	0.00

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NEUTRAL REAL INTEREST RATE ESTIMATES FOR MOZAMBIQUE[1]

The Bank of Mozambique will face sooner or later the question of when to halt cuts in the policy rate given successful disinflation. The neutral real interest rate (NRIR) is the rate at which inflation is stable around the central bank's objective and output is operating at potential. This paper presents NRIR estimates for Mozambique, applying several static and dynamic methods commonly used in the literature. The results show an NRIR range between 4.6 percent and 7.8 percent. Given current and expected inflation for Mozambique, one can argue, based on these results, that monetary policy is still somewhat tight and thus there is room to continue with the ongoing process of normalization.

A. Introduction

1. The Bank of Mozambique (BM) will face sooner or later the question of when to halt cuts in the policy rate given successful disinflation. In response to multiple shocks,[2] leading to high inflation and depreciation of the exchange rate, the BM considerably tightened monetary policy in October 2016.[3] From a peak of 26½ percent (y/y) in November 2016, inflation declined to only 3½ percent (y/y) in December 2018. Stability returned to the foreign exchange market,[4] and international reserves were rebuilt at comfortable levels.[5] In April 2017, the BM changed its operational monetary target to a short-term interest rate and started a cautious easing cycle totaling nine policy rate cuts by 900 basis points to 14¼ percent in December 2018. Monetary conditions, however, remain tight, partly reflecting the high real policy rate; real lending rates are also high and credit growth remains negative.

2. The neutral real interest rate (NRIR) is the rate at which inflation is stable around the central bank's objective and output is operating at equilibrium.[6] The NRIR is an important indicator to assess the stance of monetary policy and it is a non-observable variable. If real interest

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[2] In 2015-16, macroeconomic stability was affected by lower commodity prices, adverse weather conditions, renewed civil strife, and the disclosure of large, previously hidden SOE loans in April 2016 that subsequently led to a halt of donor budget support.

[3] The BM increased its lending rate by 600 basis points to 23¼ percent.

[4] The metical has appreciated by almost 24 percent against the U.S. dollar since October 2016.

[5] By end-March 2019, international reserves stood at 5¾ months of next year's non-megaproject imports.

[6] Wicksell's (1898, p.102 and p.120) seminal work introduced the concept stating that "[there] is a certain rate of interest on loans which is neutral in respect to commodity prices and tends neither to rise nor to lower them. This is necessarily the same as the rate of interest which would be determined by supply and demand if no use were made of money and all lending were affected in the form of real capital goods. It comes to much the same thing to describe it as the current value of the natural rate of interest on capital". Woodford (2003) presents a contemporary theoretical elaboration. Blinder (1998), Amato (2005) and Barsky et al. (2014) discuss the role of the indicator for monetary policy.

rates are above (below) the NRIR, monetary policy could be considered tight (loose) aiming at disinflation (inflation) and constraining (supporting) economic activity.

3. **This paper presents NRIR estimates for Mozambique applying several methods commonly used in the literature**. Several static (defining the NRIR as a parameterized steady state point estimate) and dynamic (estimating a time varying NRIR path) methods are available for estimating the NRIR.[7] They have been previously applied to advanced, emerging and low-income economies.[8]

4. **Static methods rely on economic theory**. The theoretical approaches underpinning the static methods are the consumption-based smoothing framework (in which the risk-free interest rate is used as a proxy for the steady state NRIR), the uncovered interest parity condition and the neoclassical growth theory.[9]

5. **Dynamic models are used to estimate a time varying NRIR and rely on econometric methods**.[10,11] The dynamic analyses include: (i) statistical/filtering techniques—such as Hodrick and Prescott filters (1997), linear de-trending, and moving averages—to real interest rates; and (ii) estimating a small scale micromodel using Kalman-filter whether constructing a reduced-form model of an IS curve and a backward looking Phillips curve, requiring the real interest rate to equal the NRIR when the output gap is zero and inflation is stable at its target (Laubach and Williams, 2003) or including variations of the Taylor rule with and without inflation expectations (Basdevant et al., 2004) or state-space models that assume a common stochastic trend between short- and long-term nominal interest rates (Fuentes and Gredig, 2007).

6. **We apply two static and two dynamic methods to parametrize NRIR estimates**.[12,13] The results range between 4.6 percent and 7.8 percent (Table 1). They indicate that Mozambique still has a somewhat tight monetary policy stance and is in the process of normalization in line with the ongoing rebalancing of the policy mix (against the backdrop of a negative output gap and low inflation). However, difficulties in treating structural breaks, uncertainties affecting risk premia and

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[7] See Giammarioli and Valla (2004) for a review.

[8] Magud and Tsounda (2012) applies the literature to a group of emerging and low-income countries in Latin America under inflation targeting or with evolving monetary regimes. Fuentes and Gredig (2007) presents results for Chile. More recently Kuhn et al. (2017) applies Laubach and Williams (2003, 2016) to South Africa.

[9] The consumption smoothing model has been applied by Campbell and Cochrane (1999) and Cochrane (2001). The uncovered interest parity condition approach is challenging to apply for countries with thinner and less liquid financial markets with structural breaks in the risk premium. Barro (2003, p.20) elaborates on the optimal level of real interest rate by equaling the long term-growth rate in the context of Phelps (1966, pp.10-18 and fn.12) the golden rule for capital accumulation.

[10] They entail a maximum likelihood estimation in conjunction with filtering techniques.

[11] For the case of Mozambique Perris and Saxegaard (2008) estimates a DSGE. The calibrated steady state implies a nominal neutral interest rate of 12.3 percent.

[12] As argued in Magud and Tsounda (2013, p.17) static approaches could be more appropriated for economies with thinner and less liquid financial markets while dynamic estimates may represent better most advanced economies.

[13] The dynamic estimations were performed with the pre-cyclone baseline. Since the supply shock is transitory and the estimation methods used medium-term forecast to eliminate end of sample bias, the average results are not expected to be affected.

the monetary regime shift in April 2017 may hinder the accuracy of NRIR estimates. In addition, these elements may adversely affect, in the dynamic models, the signaling properties of the standing lending facility rate as a proxy for the policy rate during the extended period when monetary aggregates were the nominal anchor for monetary policy.

Table 1. Mozambique: NRIR Summary Results

Consumption Smoothing Model	Uncovered Interest Rate Parity	Filters						Saving-Investment Model
		US Census Trend	Hodrick Prescott	Baxter King	Cristiano Fitzgerald Symmetric	Cristiano Fitzgerald Asymmetric	[Min, Max]	
[4.9, 7.8]	[6.3, 7.6]	4.8	4.7	4.8	5.6	4.6	[4.6, 5.6]	4.9

Source: Author's calculations.

B. Static Approaches

Consumption Based Model

7. **This approach uses the consumption-based capital asset pricing model (CAPM)**. We use Cochrane (2001) and Campbell and Cochrane (1999) without and with habit persistence, respectively, to compute the NRIR by solving the Euler equation for reasonable parameter values. The introduction of habit persistence allows for lower yield estimates that accommodate higher risk premia.[14] The models allow to determine the equilibrium real interest rate in an endowed economy populated by representative agents that maximize intertemporal utility and have access to an asset that yields a gross real return and serves to smooth consumption.

- Assuming a constant risk aversion utility function (CRRA)[15] and that aggregate consumption equals the endowment with a log-normal distributed growth rate,[16] the equilibrium interest rate implied by the model can be solved using the Euler equation as:

$$\ln R_t = r_t = -ln\beta + \gamma E_t \Delta ln y_{t+1} - \left(\frac{\gamma^2}{2}\right) Var_t(\Delta ln y_{t+1}) \quad (1)$$

Note that β is the subjective discount or time preference factor; γ is the coefficient of relative risk aversion; Δ is the difference operator; $VAR(.)$ is the variance operator; y_t is the endowment at time *t* proxied by output and r_t is the equilibrium real interest rate or neutral rate, NRIR.[17] In this approach, the neutral rate is a function of the parameters characterizing preferences and the probability distribution of the growth rate.

[14] See Cochrane (2001) and Campbell, Lo and MacKinlay (1997) for a summary of this discussion.

[15] The CRRA utility function is given by $u(c_t) = c_t^{1-\gamma}/(1-\gamma)\ \ if\ \gamma > 0, \gamma \neq 1\ or\ ln(c_t)\ if\ \gamma = 1$

[16] See Fuentes and Gredig (2007) for a derivation.

[17] The NRIR is not equal to the long run growth rate of output, implied under the golden rule in Phelps (1962), commonly used as rule of thumb to produce neutral rates estimates.

- We add habit persistence assuming a preference structure generating consumption above the habit level implying that agent risk aversion varies with the level of consumption relative to habit, x_t.[18] The Euler equation can be solved for the neutral rate assuming that the level of habit evolves slowly over time as a function of past consumption $x_t = \lambda \sum_{j=0}^{\infty} \varphi c_{t-j}$[19] and a surplus consumption ratio with an $AR(1)$ dynamics. Following Fuentes and Gredig (2007, p.4), the NRIR is given by:

  $$\ln R_t = r_t = -ln\beta + \gamma E_t \Delta ln y_{t+1} - \left(\frac{1}{2}\right)\gamma(1-\varphi) \quad (2)$$

  The first two terms are the same as in equation (1) and the last term is related with precautionary savings implying lower equilibrium real interest rate the more volatile is income.

8. Calibration. Using a measure of Mozambique's medium-term potential per capita growth rate and its volatility, we compute the NRIR for a set of plausible parameters, β and γ. The median estimate of the potential per capita output growth rate for 2004-15 is 4.37 percent,[20] with a standard deviation estimated at 1.05 percent. In the case of habit formation, the parameter φ is calibrated following the same procedure as in Fuentes and Gredig (2007, p.5).[21]

9. Results. Table 1 shows the levels of NRIR estimated with equations (1) and (2). As in Fuentes and Gerdig (2007) and Magud and Tsounda (2013), the estimates obtained without habit persistence are relatively higher than with habit persistence. To reduce the uncertainty around the effect of the time preference factor and relative risk aversion parameters, we use the set of means in Table 2. The NRIR with CRRA preferences is between 6.4 percent and 10.7 percent for the range of discount factors and risk aversion coefficients. The mean value is 8.6 percent. With habit formation, the NRIR would be in the range 4.9 percent to 7.8 percent, with a mean value of 6.4 percent. We select the results with habit formation since the NRIR without habit formation are implausibly large as documented in Cochrane (2001), Campbell et al. (1999), Magud and Tsounta (2012) and Fuentes and Gerdig (2007) for countries with similar characteristics to Mozambique.[22]

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[18] In this case the utility function is given by $u(c_t) = [(c_t - x_t) - 1]/(1-\gamma)\ \gamma > 0, \gamma \neq 1$ where $x_t$characterizes the level of habit persistence and it is assumed exogenous to simplify the analysis.

[19] φ is the weight of past consumption in the degree of habit persistence.

[20] This rate results from taking 7.27 percent for non-mining potential output growth proxied by 2004-15 average growth rate and 2.9 percent population growth rate.

[21] We assume that the Mozambican economy in 2013 (a period of relatively low policy rate, output growth around potential and low and stable inflation) had zero output gap and interest rate close to the neutral level. Using a potential per capita output growth of 4.37 percent, a real interest rate of 6.39 percent, with $\beta = 0.978$ and $\gamma = 1.5$, we obtain $\varphi = 0.973$.

[22] The introduction of habit persistence yields reasonable results for economies in process of development with relative capital scarcity and on a gradual path to financial opening with thin and less liquid domestic financial markets.

Table 2. Mozambique: NRIR based on Consumption Smoothing Models

NRIR estimates with CRRA preferences
(in percent)

β	γ 1.0	γ 1.5	γ 2.0	*Mean*
0.970	7.41	9.58	11.76	*9.58*
0.975	6.89	9.07	11.24	*9.07*
0.980	6.38	8.56	10.73	*8.56*
0.985	5.87	8.05	10.22	*8.05*
0.990	5.37	7.54	9.72	*7.54*
Mean	*6.38*	*8.56*	*10.73*	*8.56*

NRIR estimates with habit formation
(in percent)

β	γ 1.0	γ 1.5	γ 2.0	*Mean*
0.970	5.95	7.40	8.86	*7.40*
0.975	5.44	6.89	8.34	*6.89*
0.980	4.93	6.38	7.83	*6.38*
0.985	4.42	5.87	7.32	*5.87*
0.990	3.91	5.36	6.82	*5.36*
Mean	*4.93*	*6.38*	*7.83*	*6.38*

Source: Author's calculations.

Uncovered Interest Parity Condition

10. Mozambique is a small open economy where interest rates are potentially arbitrated. Assuming no-arbitrage conditions in a model with capital movement, the NRIR can be estimated by using the uncovered parity condition,[23] substituting the expected nominal rate of depreciation with the real exchange rate depreciation[24] and solving for the real interest rate, r. After substitution, we get an uncovered parity condition in real terms:

$$r = i - \pi = i^* - \pi^* + \widehat{RER} + \rho = r^* + \widehat{RER} + \rho \qquad (3)$$

11. Calibration. If we take the medium-term values for the components of equation (3), we can derive the NRIR. For r^* we take the average NRIR for the U.S. economy estimated by Holston, Laubach and Williams (2017) for 2008-18.[25] To obtain $\widehat{RER}$ we use the average real effective exchange rate depreciation for the available BM historical series for 2011-18. For the country-specific risk premium, we consider alternative measures including the country risk component by the Mozambican Association of Banks (AMB) when setting the standardized prime lending rate and Damodaran computations considering a group of country comparators.[26]

12. The results are shown in Table 3. NRIR estimates fall in the relatively narrow range of 6.3 percent to 7.6 percent.

[23] The equilibrium level for the nominal interest rate correcting the international interest rate, i^*,with the expected depreciation of the nominal exchange rate, $\hat{E}$, and the risk premium, ρ; is given by $i = i^* + \hat{E} + \rho$.

[24] The expected nominal exchange rate depreciation could be derived taking the first difference from the real exchange rate definition in log terms yielding $\hat{E} = \widehat{RER} + \pi - \pi^*$. Note that $r \equiv i - \pi$, $r^* \equiv i^* - \pi^*$, and $RER \equiv P^*E/P$, and π (π^*) denotes the domestic (international) inflation rate derived from the first difference of the natural logarithm of the domestic (international) price level, (P^*).

[25] Current model estimates from Holston, Laubach and Williams (2017) are available at https://www.newyorkfed.org/research/policy/rstar.

[26] See Damodaran (2018) calculations at http://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/ctryprem.html.

Table 3. Mozambique: NRIR from Interest Rate Parity
(Percent)

	Value	Comment
r^*	0.6	Holston, Laubach and Williams (2018)
$\widehat{RER}$	1.7	Average real effective exchange rate depreciation
ρ	[4.0, 5.3]	Average of high and low estimates from Mozambican Banking Association (ABM), and Damodaran (2018).
r	[6.3, 7.6]	

Source: Authors' calculations.

C. Dynamic Approaches

Statistical Filters

13. We apply the U.S. Census, Hodrick-Prescott, Baxter-King, Christiano-Fitzgerald (symmetric and asymmetric) filters on policy rate series.[27] In all dynamic estimations, we focus on the monthly policy rate series deflated by 12-month inflation. To minimize the end-of-sample bias, we forecast the real policy rate over 84 months[28] using Census X-13 and seasonally autoregressive integrated moving average process (SARIMA).[29]

14. The **results** are presented in Table 4. NRIR estimates fall in the relatively narrow range of 4.6 percent to 5.6 percent, with an average of 4.9 percent. These projections will be used in the dynamic estimation to minimize the end-of-sample bias.[30]

Table 4. Mozambique: NRIR Filters Results
(Percent)

Filters						
US Census Trend	Hodrick Prescott	Baxter King	Cristiano Fitzgerald Symmetric	Cristiano Fitzgerald Asymmetri	[Min, Max]	Average
4.8	4.7	4.8	5.6	4.6	[4.6-5.6]	4.9

Source: Author's calculations.

[27] For the period before the MIMO rate we use BM lending facility rate.

[28] This long forecast horizon is required to absorb the risk premium shock.

[29] Census X-13 and SARIMA process are used to adjust form outliers and any seasonality.

[30] Statistical filters tend to be bias by putting more weight on the most recent observations of the data series.

Savings-Investment Macroeconomic Model

15. This approach uses economic relationships to obtain a joint distribution of the NRIR and growth potential based on a semi-structural macroeconomic model using Laubach and Williams (2003). The model stylizes the aggregate demand and supply equilibrium in terms of the savings-investment balance with a backward-looking IS equation relating the output gap and the NRIR, and a Philips curve relating inflation to the output gap. In equilibrium, the output gap in each period is closed, inflation is at target level and the real interest rate equals the NRIR.

- The IS equation is expressed in log-deviations of real GDP from potential (the output gap), $y_t - y_t^*$, as a linear function of its lags (i.e. assuming a slow reaction of output), lagged deviations of the actual real policy rate from the NRIR, $r_t - r_t^*$, and a vector with control variables for the output gap, $x_{1,t}^T$, with cyclical deviations of the real exchange rate estimated using an HP-filter for the trend.[31] The error term $\varepsilon_t^y \sim N(0, \sigma_y^2)$ is a white noise process. So, we have:

$$(y_t - y_t^*) = \sum_{s=1}^{S} \alpha_s^y (y_{t-s} - y_{t-s}^*) + \sum_{v=1}^{V} \alpha_v^r (r_{t-v} - r_{t-v}^*) + x_{1,t}^T \alpha + \varepsilon_t^y \quad (4)$$

- The Phillips curve expresses the inflation gap from the implicit target $\hat{\pi}_t$ subject to some degree of persistence captured by its own lags and depends on the output gap and a vector of inflation controls $x_{2,t}^T$ with cyclical deviations of the real exchange rate, oil prices, commodity prices estimated using HP filter for their respective trends. The targets were proxied using inflation average and level shifts over inflation cycles. The error term $\varepsilon_t^\pi \sim N(0, \sigma_\pi^2)$ is a white noise process. In this case, we have:

$$(\pi_t - \pi_t^*) = \sum_{p=1}^{P} \beta_p^\pi (\pi_{t-p} - \pi_{t-p}^*) + \sum_{q=1}^{Q} \beta_q^y (y_{t-q} - y_{t-q}^*) + x_{2,t}^T \beta + \varepsilon_t^\pi \quad (5)$$

16. The NRIR and potential output are estimated using the Kalman-filter approach. To model potential output and NRIR dynamics we assume potential output growth at a rate g following a random walk process and that the NRIR is linked to the dynamics of the growth trend. This analysis implies a semi-structural approach to the NRIR beyond the business cycle with a metric that gravitates around potential output growth and non-growth factors.[32]

- These dynamics are given by equations (6.1), (6.2) and (7):

$$y_t^* = y_{t-1}^* + g_{t-1} \quad (6.1)$$

$$g_t = g_{t-1} + \varepsilon_t^g, \varepsilon_t^g \sim N(0, \sigma_r^2) \quad (6.2)$$

$$r_t^* = c g_t + \varepsilon_t^r, \varepsilon_t^r \sim N(0, \sigma_r^2) \quad (7)$$

[31] See Kara et. all (2007) for details.

[32] We also estimate a simpler model with neutral rates following a random walk process. The results were robust to this change of specification.

17. Estimations were carried out using quarterly data from 2008 to 2018 and forecast to mitigate end-sample bias.[33] We used seasonally-adjusted data for national inflation[34] and quarterly GDP. Inflation deviations are computed using targets proxied by using inflation average and level shifts over inflation cycles. To eliminate serial correlation in residuals, one lag of inflation deviations is used in equation (4) and one lag for both output and interest rate gaps in equations (3) and (4). As additional controls, in the Phillips curve (in vector $x_{2,t}^{T}$) we include the percentage deviation of both the oil-price inflation and the real exchange rate from their respective HP trends, using the smoothing parameter at 200. Meanwhile, in the IS curve (in vector $x_{1,t}^{T}$) we only include the real exchange rate deviation from the HP trend.

18. The results yield a NRIR around 4.7 percent in terms of the average for 2012-18 and of 4.9 percent over the projection period. Note that estimates show an increase in NRIR from 2012 to mid-2014 (from 4 percent to 5.2 percent) and a decline from 2016 until the first quarter of 2017 (to 4 percent) when it starts to recover to its average level.

19. These results are subject to uncertainty, however. The monetary policy regime shift in April 2017 may hinder the accuracy of the NRIR estimates since proxying the policy rate with the standing lending facility rate prior to April 2017 may not capture the policy stance of the previous regime that relied on monetary aggregates as an intermediate variable.[35] Estimates with a Quarterly Projection Model (QPM) model may help to assess the uncertainty of estimates by incorporating the monetary regime shift explicitly and allow for treatments of transitory supply shocks.[36,37] In addition, the combined shocks the Mozambican economy faced in 2015-16 may be not be captured well in the controls used in the semi-structural approach.

D. Main Findings

20. Following a monetary policy tightening cycle that led to successful disinflation, the BM will face sooner or later the question of when to halt cuts in the policy rate. This paper estimated for Mozambique the NRIR, which is an important indicator to assess the current stance of monetary policy.

21. The results highlight two facts. First, despite differences in methodologies, and notwithstanding limitations of the approaches, NRIR estimates for Mozambique are clustered

[33] The results are robust to forecast windows between 12 and 28 quarters.

[34] The results are robust using core inflation rate excluding fruits, vegetables and administered prices.

[35] See Aisen and Simone (2018, pp.4-15) for an analysis of the transition to a new monetary policy regime.

[36] Adding dynamic approaches would contribute to better understand the NRIR dynamics. Estimating a dynamic stochastic general equilibrium model (DSGE) or calibrating a QPM where NRIR is interpreted as the real interest rate in a model with sticky prices based on New-Keynesian theory are avenues to be explored in further work.

[37] The BM is enhancing its capacities for forward-looking monetary policy formulation decision making. Since 2008, the IMF is providing TA to develop a full-fledged Forecasting and Policy Analysis System (FPAS). The BM's Department of Economic Studies has a well-established core modeling team and a QPM core model used to provide inputs to the monetary policy committee. The QPM calibration contains a convergent time varying path for the NRIR based on a version of the uncovered interest parity condition approach considering the effect of indebtedness on the country risk premium.

within a relatively narrow band, ranging from 4.6 percent to 7.8 percent. Assuming inflation expectations anchored around 5.5 percent, the corresponding neutral nominal interest rate (NNIR) would range from 10.1 percent to 13.2 percent.[38] Second, the width of the range highlights not only the uncertainty surrounding estimates/methods used but also the role of country risk premium and international financial conditions. Furthermore, difficulties in treating structural breaks, including the monetary policy regime shift in April 2017, may hinder the accuracy of the estimates because these elements may adversely affect the signaling properties of the standing lending rate as a proxy for the policy rate during the extended period when monetary aggregates were the nominal anchor for monetary policy.

22. Like in other countries, the NRIR for Mozambique is time-varying. The Laubach and Williams (2003) approach yields a NRIR of around 4.7 percent in terms of the average for 2012-18 and of 4.9 over the projection period. Note that this approach estimates an increase in the NRIR from 2012 to mid-2014 (from 4 percent to 5.2 percent) and a decline from 2016 until the fourth quarter of 2017 (to 4 percent) when it starts to recover to its average level.

23. The results above, however, indicate that Mozambique still has a somewhat tight monetary policy stance and is in the process of normalization. This normalization is in line with the ongoing rebalancing of the policy mix against the backdrop of a negative output gap, expected inflation to remain within a single-digit band and domestic and external risks.

[38] Aisen and Simione (2018, p.5 and Box 1, p. 9) consider the current monetary regime evolving towards inflation targeting where the "medium-term inflation objective remains 5-6 percent as set by the Government". In the process of strengthening governance and modernizing operations, the BM may set an explicit and publicly known numerical inflation objective for the medium-term narrowing its current commitment to keep inflation low within one single digit and strengthening the expectational channel.

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