VŠE / FACULTY OF INTERNATIONAL RELATIONS

Working Paper Series

Optimal Public Investment in Resource-Rich Low-Income Countries

Working Paper 2020 - 04

Aliya Algozhina

ISSN 2695-0820

Optimal Public Investment in Resource-Rich Low-Income Countries

Aliya Algozhina*

November 26, 2020

Abstract

Recent studies have found that resource-rich low-income countries are better off investing their resource revenues domestically rather than saving them abroad in a sovereign wealth fund (SWF). This paper finds an optimal rule-based policy of accumulating public capital and its associated public investment path in a perfect foresight general equilibrium model. The model has several specific features different from the existing frameworks: The policy rule for public capital is introduced. Public investment is inefficient and has its absorptive capacity constraint costs. External savings clear the government budget. There is a variable share of resource revenues to accumulate the SWF, and the natural resource sector is assumed to be capital-intensive with its FDI shock. Based on calibration for African countries, the study finds that the front-loaded public investment path is optimal given an initial one-period resource windfall, public investment inefficiency, and absorptive capacity constraints in the economies. This result also holds under less productive public capital, while a scenario of no resource windfall produces the welfare loss due to a steady increase in consumption tax to finance public investment.

Keywords: public investment, public capital, absorptive capacity constraint, resource windfall, SWF

JEL Classification: E22, E62, F41, H54, O55, Q32

*Prague University of Economics and Business (VŠE), W. Churchill sq. 1938/4, Prague 3, 13067, Czech Republic. E-mail: aliya.algozhina@vse.cz.

1 Introduction

Resource-rich low-income countries are often considered as the most vulnerable economies in the world for three basic reasons. First, they are exposed to volatile external shocks: commodity world price fluctuations, capital inflows/outflows, and geological discovery/depletion of natural resources. Second, they are prone to a resource curse due to weak institutions,[1] inefficient governance, high income inequality, and Dutch Disease issue.[2] Third, their current generation is poor living in an environment of capital scarcity,[3] underdeveloped financial system, and high absorptive costs for investment to build home-grown capital (van der Ploeg, 2012). In such specific conditions, finding an optimal rule-based policy to manage resource windfalls with a sustainable development objective is crucial but challenging.

Several studies have recently concluded that resource abundant developing economies are better off investing their resource windfalls domestically rather than saving them abroad in a Sovereign Wealth Fund (SWF) for future generations (Alter et al., 2017; Delechat et al., 2017; Li et al., 2017; Melina et al., 2016; Richmond et al., 2015; Berg et al., 2013; van der Ploeg and Venables, 2011; Collier et al., 2010). This is due to a lack of growth-inducing domestic capital such as infrastructure, educated/skilled labor, and health services which have higher social value and returns than foreign assets in those economies. The fact of poor, impatient, and credit-constrained current households, who need to consume now, suggests a policy of benefiting them as opposed to saving for future individuals who may well be in a relatively wealthier position given a sustainable development path over time. However, turning resource windfalls into transfers to households cannot be an appropriate policy because private spending of those transfers may result in inefficient consumption, the increase of which is unsustainable. Investment in the domestic economy, in contrast, puts consumption on a rising path and brings forward the growth trajectory, benefiting all generations.

Public investment of resource revenues in infrastructure is consistently recommended in the context of low-income countries. The more and better their infrastructure, the lower production costs and the higher productivity effects of private inputs. Calderon and Serven (2010) find

[1]According to Mehlum et al. (2006), resource abundant countries with grabber friendly institutions lose in terms of their growth, while producer friendly institutions lead to higher growth. Furthermore, Boschini et al. (2007) find that the resource curse occurs if low-quality institutions are combined with diamonds and precious metals, as opposed to minerals. From the political economy point of view, the resource curse seems to be driven by presidential regimes, not parliamentary democracies (Andersen and Aslaksen, 2008).

[2]The Dutch Disease is associated with a negative effect of resource boom on manufacturing, which is an alternative traded goods sector leading essentially to sustainable growth. This negative effect occurs because the booming sector draws production factors out of other sectors and also due to a real appreciation of exchange rate (i.e. a rise in the relative price of non-traded goods), since the increased income resulting from the boom is spent on non-traded goods (Corden and Neary, 1982).

[3]Capital scarcity, hereafter, refers to a lack of physical and human capital. I do not mean its modeling through a high risk premium which developing countries may face when they borrow from abroad to finance their investment projects (van der Ploeg and Venables, 2011; van den Bremer and van der Ploeg, 2013).

that an increased volume of infrastructure stocks and an improved quality of infrastructure services have a positive impact on long-run growth and a negative impact on income inequality in Sub-Saharan Africa. Yogo and Verdier-Chouchane (2015), in turn, estimates that a 1 percent increase in infrastructure quality raises competitiveness by 0.64 percent in North Africa where there is a progress in terms of infrastructure quantity relative to Sub-Saharan Africa, to begin with.

The existing literature frequently highlights two issues relevant to resource-rich developing economies that are important to distinguish: an inefficiency of public investment and absorptive capacity constraints. Public investment is inefficient if one dollar of it accumulates public capital by less than one. In other words, there is a loss in public investment or large costs to effectively accumulate capital due to the corrupted governments. This is especially true when the government is a major investor as opposed to multiple private ones. Pritchett (2000), in this respect, has criticized conclusions made by the cross-country empirical studies relating public investment or capital to output differences. He says that stating as "capital does not account for a large fraction of cross national output differences" versus more accurate "differences in what governments run by corrupt autocrats/oligarchs/dictators spent in the past and was recorded as investment does not explain current output" (Pritchett, 2000, p. 381) leads to very different policy implications and research directions. Gupta et al. (2014) have therefore constructed a new dataset on public capital by correcting for public investment inefficiency. They found that the stock of effective public capital might be up to one-half of the stock computed by the traditional method, and the productivity of effective capital is significantly higher than the marginal cost of funds.

In contrast to public investment inefficiency—related to corruption, rent-seeking behavior, delays due to bureaucracy, white elephant projects, and other distorted incentives—absorptive capacity constraint seems to be a structural problem stemming from capital scarcity. Absorption constraints can be understood in four ways. First is in a context of investment speed. If developing economies ramp up their public investment while having a lack of public capital, then capacity is still limited to effectively absorb the scaled-up investment and may not result in a desired accumulation of public capital. In other words, some bottlenecks may arise if to increase suddenly public spending; roads, bridges, etc. get congested, and a shortage of particular public goods or labor skills becomes apparent. Second is so-called "investing to invest", when the shortage of domestically produced public goods is addressed by investing more in home-grown public capital to expand the domestic capacity. "Put differently, teachers are needed to educate more teachers, nurses are needed to train more nurses, roads are needed to produce more roads, etc." (van der Ploeg, 2012, p. 528). Third is about network effects. In order to deliver a certain good or provide a certain service, many complementary components of infrastructure should be put in place in an interconnected network. Until this basic network is established, an additional increase of public investment does not bring productivity gains. "Having electricity to produce commodities in rural areas but no roads to carry them to urban markets limits the productivity effects of a program designed to increase access to energy." (Agenor, 2010, p. 933). Fourth is related to a lack of spending on public capital maintenance as opposed to "new" capital. Low-income countries often have too depreciated infrastructure and thus technically inefficient in its functioning, which causes losses for the private sector. According to Agenor (2009), increased maintenance expenditure would improve the durability and the efficiency of public capital, enhancing its productivity effects on private production and stimulating growth.

Because of public investment inefficiency and absorptive capacity constraints, a gradual scaling-up of public investment financed by resource revenues is recommended by several studies in a DSGE framework (Li et al., 2017; Delechat et al., 2017; Melina et al., 2016; Richmond et al., 2015; Berg et al., 2013). For example, Richmond et al. (2015) advocate that the moderate scaling-up of public investment should be preferred because of having a buffer at times when an adverse resource shock hits the economy, and it would be still possible to maintain public capital thanks to external savings. An aggressive investment strategy, in contrast, depletes the external buffer and cannot sustain the same investment when there is a negative resource shock. They apply their model to the case of Angola in this matter:

> Angola is the second largest oil exporter in Africa, and oil revenue has accounted for more than 75% of total revenue since 2002. During the oil price boom of 2003–2008, Angola started rebuilding infrastructure destroyed during the civil war that ended in 2002. The persistent surges in oil revenues led to aggressive fiscal expansion from 2006 to 2008, leaving Angola to face the decline in oil prices during 2008–2009 with depleted external and fiscal buffers. The experience led to a lively public policy debate on how to take the lessons of the crisis and build a more resilient public investment program for the future. (Richmond et al., 2015, p. 195)

However, Collier et al. (2010) have earlier recommended a sovereign liquidity fund by parking some savings at times of high resource revenues, in order to protect public investment at times of low resource revenues. This liquidity fund would differ from the SWF in terms of its scale and composition of assets which need to be short term. The idea of establishing the parking fund has been also suggested by van der Ploeg (2011), but with a purpose to wait, as absorptive capacity constraints being resolved, until home-grown capital is accumulated enough to sensibly invest in the domestic economy.

A major drawback of studies listed above is that they examine exogenous public investment paths, which vary in terms of their scaling-up magnitude, and select the appropriate one among them. Only Alter et al. (2017) find an optimal public investment path in the similar DSGE framework à la Berg et al. (2013). The shape of this optimal path appears to be front-loaded as opposed to the gradual scaling-up of public investment, even though both of them can be interpreted as being moderate.

This paper develops a model which is a simplified version of Alter et al. (2017) or an extension of the perfect foresight general equilibrium framework of Berg et al. (2013). The objective of this study is to find an optimal policy rule for public capital that is pinned down by two parameters—a new steady state level of increased public capital and its adjustment speed. These are found on a grid to maximize the household's utility. Since public capital is a stock variable, an associated optimal public investment path can be obtained accordingly. This paper extends Berg et al. (2013) in several respects: The policy rule for public capital is introduced. Public investment is inefficient and also has its absorptive capacity constraint costs. External savings clear the government budget. There is a variable share of resource revenues to accumulate the SWF, and the natural resource sector is assumed to be capital-intensive with its FDI shock. In terms of the simplification of Alter et al. (2017), this paper does not have foreign debt and public debt; public investment inefficiency is captured by a single parameter, and the SWF evolves in a different way.

In section two, the model is outlined representing households, producers of traded and non-traded goods, natural resource sector, and fiscal policy. Section three describes the calibration of parameters, the list of which is provided in Appendix A. Section four discusses the findings of optimal policy for public capital and public investment at different absorptive capacity constraints. Sensitivity analysis to a reduced output elasticity of public capital is presented in section five, including a scenario of no resource windfall shock. Section six concludes.

2 Model

The model is a small open, real economy with no external public or private debt, but with FDI in the natural resource sector. This "closed" assumption of financial account captures the limited access of low-income countries to foreign funds and facilitates the study of an increase of public investment solely financed by a resource windfall, rather than by external borrowing. The domestic public debt is fixed to avoid a drop in household's consumption which may occur due to increased savings in the government bonds that finance the scaling-up of public investment.

This is the perfect foresight general equilibrium model that has a representative household who consumes and pays consumption tax, supplies labor and pays fixed labor tax, owns firms of traded and non-traded goods, holds a constant amount of government bonds and receives fixed remittances from abroad and fixed transfers from the government budget. The producers of traded and non-traded goods are perfectly competitive, who differ in terms of their TFP, and have public capital as an additional input in their Cobb-Douglass production function. The natural resource sector is assumed to be capital-intensive with its real FDI shock, thus there is no labor input in this sector to avoid the complications from possible labor mobility. Public investment ineffectively accumulates public capital and, in addition, has absorptive capacity constraints modeled differently from Berg et al. (2013), Alter et al. (2017) or Agenor (2016).

2.1 Households

A representative household maximizes its expected utility by choosing composite consumption C_t and labor L_t:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{1}{1-\sigma} C_t^{1-\sigma} - \frac{\kappa}{1+\psi} L_t^{1+\psi} \right] \tag{1}$$

subject to the budget constraint:

$$(1+\tau_t^c)C_t + B = (1-\tau^l)w_t L_t + RB + \Omega_t^T + \Omega_t^N + s_t RM^* + Z, \tag{2}$$

where σ and ψ are the inverses of the elasticity of intertemporal substitution for consumption and labor, τ_t^c and τ^l are the consumption and labor tax rates, Ω_t^T and Ω_t^N are the real profits transferred from the producers of traded and non-traded goods, s_t is a CPI-based real exchange rate, RM^* is remittances in the units of foreign consumption (denoted by an asterisk), Z is the government transfers, B is the government bonds, and R is the domestic real interest rate.

The composite CES consumption bundle C_t includes traded (C_t^T) and non-traded (C_t^N) goods:

$$C_t = \left[\varphi^{\frac{1}{\chi}} (C_t^N)^{\frac{\chi-1}{\chi}} + (1-\varphi)^{\frac{1}{\chi}} (C_t^T)^{\frac{\chi-1}{\chi}} \right]^{\frac{\chi}{\chi-1}}, \tag{3}$$

where φ is a consumption home-bias parameter and χ is the intratemporal elasticity of substitution between traded and non-traded goods. Composite consumption is set as a numeraire for the economy, so that by the assumed law of one price for traded goods, s_t is also the relative price of traded goods to composite consumption, while p_t^N is the relative price of non-traded goods to composite consumption:

$$1 = \varphi (p_t^N)^{1-\chi} + (1-\varphi) s_t^{1-\chi} \tag{4}$$

Labor supply of the household consists of labor efforts made in the traded (L_t^T) and non-traded (L_t^N) sectors with ρ as an elasticity of substitution; thus, there is an imperfect labor mobility between these two sectors:

$$L_t = \left[\delta^{-\frac{1}{\rho}} (L_t^N)^{\frac{1+\rho}{\rho}} + (1-\delta)^{-\frac{1}{\rho}} (L_t^T)^{\frac{1+\rho}{\rho}} \right]^{\frac{\rho}{1+\rho}} \tag{5}$$

Real wage index combines the real wage rates in each sector:

$$w_t = \left[\delta (w_t^N)^{1+\rho} + (1-\delta)(w_t^T)^{1+\rho} \right]^{\frac{1}{1+\rho}} \tag{6}$$

2.2 Producers of traded and non-traded goods

The Cobb-Douglass production function of sector $j \in \{T, N\}$ includes public capital K_{t-1}^G as an additional input with its output elasticity of α^G:

$$Y_t^j = z_t^j (K_{t-1}^j)^{1-\alpha^j} (L_t^j)^{\alpha^j} (K_{t-1}^G)^{\alpha^G} \tag{7}$$

The law of motion for private capital has quadratic investment adjustment costs with a relevant parameter $\kappa^j > 0$:

$$K_t^j = (1-\delta^j)K_{t-1}^j + \left[1 - \frac{\kappa^j}{2}\left(\frac{I_t^j}{I_{t-1}^j} - 1\right)^2\right] I_t^j \tag{8}$$

The traded and non-traded goods sectors are perfectly competitive and differ in terms of their TFP to capture the Dutch Disease. There is a constant TFP parameter z^N for the non-traded sector, and learning-by-doing externalities, in a form of dependence on the lagged output, are in the TFP of the traded sector:

$$z_t^N = z^N, \qquad \ln z_t^T = \rho_{zT} \ln z_{t-1}^T + d \ln Y_{t-1}^T \tag{9}$$

If there is the Dutch Disease such that the traded goods output falls due to the resource boom, then the learning-by-doing externalities reduce the productivity of traded sector further, making the Dutch Disease persistent. However, if the resource revenues are effectively invested to sufficiently accumulate public capital, which is a production input, then the productivity of traded sector enhances, and the learning-by-doing induced technological progress can reverse the Dutch Disease and lead to economic growth.[4]

The producers maximize their net present value profits, weighted by the marginal utility of household λ_t,:

$$E_0 \sum_{t=0}^{\infty} \beta^t \lambda_t \underbrace{[p_t^j Y_t^j - w_t^j L_t^j - I_t^j]}_{=\Omega_t^j} \tag{10}$$

through choosing labor, capital, and investment subject to the capital accumulation equation (8).

2.3 Natural resource sector

The natural resource sector is often modeled as an exogenous process for resource output directly. However, if to make it more specific and closer to the reality of developing countries (footnote 13 in Melina et al., 2016), then FDI is present in the resource sector. In this model, the natural resource sector is assumed to be capital-intensive and has only capital input:

$$Y_t^o = z_t^o (K_{t-1}^o)^{\alpha^o}, \tag{11}$$

which is accumulated by FDI denominated in the foreign consumption goods.

$$K_t^o = (1-\delta^o)K_{t-1}^o + FDI_t^* \tag{12}$$

The productivity of resource sector is decaying exponentially: $z_t^o = 0.95 z_{t-1}^o$.

[4] van Wijnbergen (1984) showed that in order to correct the Dutch Disease the government intervention is needed: In his model, it is a subsidy to manufacturing sector which should increase if oil revenues are used for consumption and do not accumulate the SWF.

The only exogenous shock is a real FDI shock affecting the resource output through its capital. This explicit mechanism is just another way to model the same exogenous resource output.

$$\ln FDI_t^* = \rho_{FDI} \ln FDI_{t-1}^* + \varepsilon_t^{FDI} \tag{13}$$

The profits of the resource sector include royalties levied on production quantity at a rate τ^o:

$$\Omega_t^{o*} = (1 - \tau^o) Y_t^o \tag{14}$$

The resource sector is owned by the foreigners and government. The dividend share of resource profits that the government receives is denoted by ι^{div}. The resource revenues consist of royalties and dividends:

$$T_t^o = s_t [\tau^o Y_t^o + \iota^{div} \Omega_t^{o*}] \tag{15}$$

2.4 Fiscal policy

The government collects its resource revenues T_t^o, non-resource revenues T_t^{NO} representing consumption and labor taxes, and interest income from the SWF. Fiscal expenditures include transfers, interest payments on the bonds, and government purchases which are a sum of public consumption and public investment. Thus, the government budget constraint is as follows:

$$ES_t = T_t^o + \underbrace{\tau_t^c C_t + \tau^l w_t L_t}_{T_t^{NO}} + s_t r^* SWF_{t-1}^* - Z - (RB - B) - p_t^G \underbrace{(G_t^C + G_t^I)}_{G_t}, \tag{16}$$

where a residual variable ES_t indicates the external savings that accumulate the SWF. The external savings themselves are a time-varying share of resource revenues ϕ_t.

$$SWF_t^* = \rho_{swf} SWF_{t-1}^* + \frac{ES_t}{s_t}, \qquad ES_t = \phi_t T_t^o, \qquad \phi_t = \phi \frac{T_t^o}{T^o} \tag{17}$$

The policy rule to be examined for the optimal increase of public capital $\frac{K_{nss}^G}{K^G}$ and adjustment speed γ is as follows:

$$K_t^G = (1 - e^{-\gamma t}) K_{nss}^G + e^{-\gamma t} K^G, \tag{18}$$

where K_{nss}^G is a new steady state public capital, while K^G is an initial steady state level of public capital.

Public capital accumulation involves the effective public investment $\epsilon \tilde{G_t^I}$ with its absorptive capacity constraint costs pinned down by the parameter $b > 0$, which is different from ϵ:

$$K_t^G = (1 - \delta^g) K_{t-1}^G + \epsilon \tilde{G_t^I}, \qquad \tilde{G_t^I} = \left[1 - b \left(\frac{G_t^I}{G^I} - 1 \right)^2 \right] G_t^I \tag{19}$$

This simple way of separating public investment inefficiency, related to corruption and other distorted incentives, from the absorptive capacity constraint, which might be a structural issue, is the alternative modeling approach among existing ones laid down in Berg et al. (2013) or Agenor (2016).

Similar to private consumption, government purchases are the CES bundle of traded and non-traded goods with a variable degree of home-bias ν_t:

$$G_t = \left[\nu_t^{\frac{1}{\chi}}(G_t^N)^{\frac{\chi-1}{\chi}} + (1-\nu_t)^{\frac{1}{\chi}}(G_t^T)^{\frac{\chi-1}{\chi}}\right]^{\frac{\chi}{\chi-1}} \tag{20}$$

This parameter is time-varying, according to Berg et al. (2013), to distinguish the home-bias of additional public spending ν_g from its steady state value ν, since the analysis focuses on the allocation of additional public spending to public investment:

$$\nu_t = \nu + (\nu_g - \nu)\frac{p_t^G G_t - p^G G}{p_t^G G_t} \tag{21}$$

The relative price of government purchases to composite consumption is as follows, accordingly:

$$p_t^G = [\nu_t(p_t^N)^{1-\chi} + (1-\nu_t)s_t^{1-\chi}]^{\frac{1}{1-\chi}} \tag{22}$$

2.5 Market clearing conditions

The market clearing condition for the non-traded goods sector requires that its supply is equal to demand:

$$Y_t^N = (p_t^N)^{-\chi}\underbrace{[\varphi(C_t + I_t^N + I_t^T) + \nu_t(p_t^G)^{\chi}G_t]}_{D_t^N} \tag{23}$$

Aggregate output consists of traded, non-traded, and resource sectors' output:

$$Y_t = s_t Y_t^T + p_t^N Y_t^N + s_t Y_t^o \tag{24}$$

Current account deficit includes the domestic absorption, output, remittances, and interest income of SWF:

$$CA_t^d = (C_t + \underbrace{I_t^T + I_t^N + s_t FDI_t^*}_{I_t} + p_t^G G_t) - Y_t - s_t[RM^* + r^* SWF_{t-1}^*] \tag{25}$$

The balance of payments is specified by the following variables: current account deficit, FDI, foreign share of resource profits, and the difference of SWF assets.

$$CA_t^d = s_t[FDI_t^* - (1-\iota^{div})\Omega_t^{o*} - (SWF_t^* - \rho_{swf}SWF_{t-1}^*)] \tag{26}$$

The equilibrium system of equations consists of solutions to the household's and firms' optimization problems, private and public capital accumulation equations, government budget constraint, fiscal policy, SWF accumulation, price equations, market clearing conditions, balance of payments equation, and FDI process. The dynamics of the model are driven by a large temporal FDI shock, so that resource output eventually reverts to its pre-windfall level. The equilibrium is solved non-linearly from the initial pre-windfall steady state to a new steady state of increased public capital.

3 Calibration

The model is calibrated on annual data for the Central African Economic and Monetary Community (CEMAC) which includes Cameroon, Chad, the Central African Republic, Congo, Gabon, and Equatorial Guinea. Since the early 2000s, five of the six CEMAC countries have been experiencing a rapidly rising oil income due to increased oil exports and fiscal revenues, except the Central African Republic. Oil is about 40 percent of regional GDP and 85 percent of total exports. The living standards, however, have not improved as most of population need an access to electricity, road networks, safe water supply, and sanitation (Akitoby and Coorey, 2012).

The following several parameters are specifically calibrated for this model, while the rest are consistent with Berg et al. (2013). The FDI shock persistence is set to 0.8 with a standard deviation of 6.26 to double the resource output-to-GDP ratio over the next ten years. The domestic real interest rate is 10 percent, giving a discount factor of 0.91 associated with the presence of impatient households. The SWF earns a real return of 2.7 percent, whereas public capital due to its scarcity has a higher net return of 9.12 percent at its output elasticity of 0.1 and annual depreciation rate of 10 percent.

As a sensitivity test, the return on public capital (1.47 percent) lower than the SWF's interest rate is also examined by changing its output elasticity to 0.06. The tightness of absorptive capacity constraints b is varied across 0.1, 0.2, and 0.3 to observe the differences in optimal increase of public investment. The list of all parameters is provided in Appendix A.

4 Results

According to the equation (18) $K_t^G = (1 - e^{-\gamma t})K_{nss}^G + e^{-\gamma t}K^G$, the optimal policy parameters to increase public capital are found in two steps. First, a search of welfare-maximizing public capital at a new steady state K_{nss}^G is implemented based on the discounted sum of household's utility. Second, given this optimal level of public capital, the utility-maximizing adjustment speed γ is found over a 100-year period. These two steps are repeated at each absorptive capacity constraint b, in the equation (19), which characterizes a tightness of public investment costs in the economy. Technically, the non-linear model is solved in such a way that external savings eventually clear the government budget constraint, and public investment adjusts to avoid an initial hike in consumption tax rate.

Table 1. **Main results:** $\alpha^G = 0.1$	$b = 0.1$	$b = 0.2$	$b = 0.3$
Optimal increase of public capital	64.74%	44.15%	35.32%
Optimal adjustment speed	0.16	0.14	0.14
Optimal increase of public investment at new SS	74.4%	52.6%	43.4%
Overshooting magnitude of public investment	102%	79%	71.1%
Overshooting magnitude of effective public investment	81.1%	56.7%	45.2%
Consumption tax rate increase at new SS	39.4%	27.9%	23.2%
St dev of consumption growth over first 10 years	1.36	0.75	0.76
Welfare gain w.r.t. original pre-windfall steady state	3.2%	2.5%	2.1%

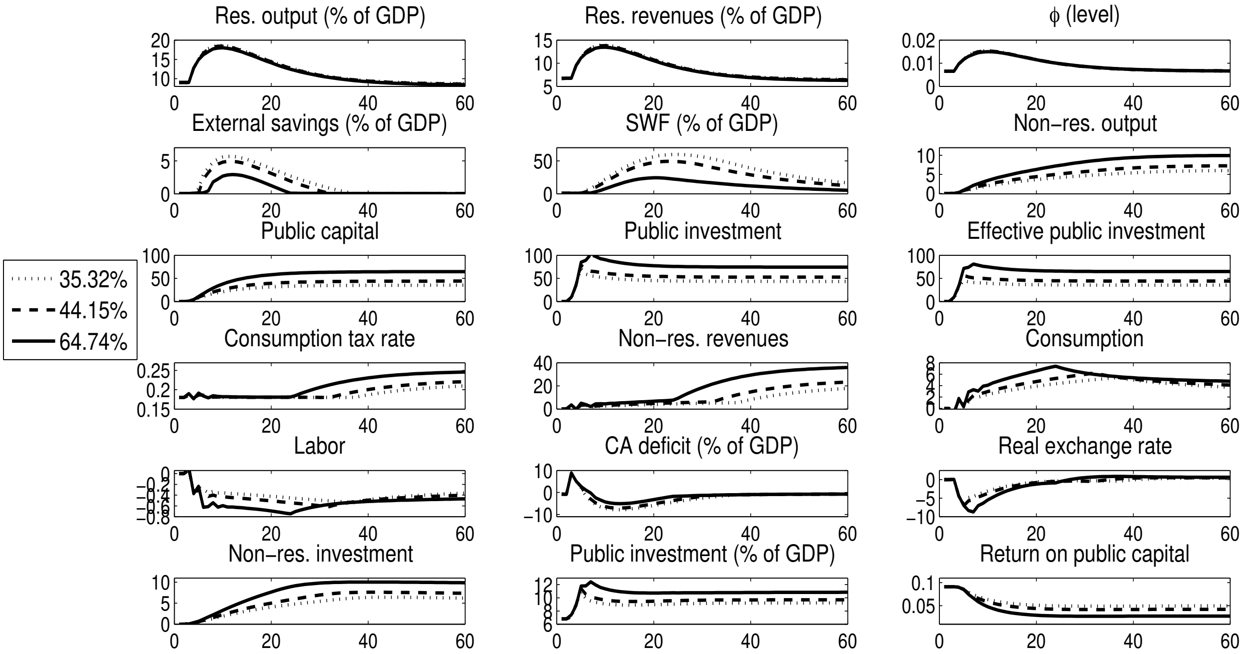
The tightness of absorptive capacity constraints b in the equation (19) is varied across 0.1, 0.2, and 0.3.

The main results are summarized in Table 1. The parameter $b = 0.3$ can be interpreted as \$0.6604 effective public investment accumulating public capital per \$1 invested. As absorptive capacity constraints become less tight (b declines), the effective public investment per \$1 invested increases (up to \$0.6613), and the optimal levels of public capital and public investment rise which are the highest at $b = 0.1$. The adjustment speed to reach the new increased level of public capital appears to be at its value which produces a front-loaded public investment path that turns out to be optimal across all b. The respective magnitude of public investment overshooting its increase at a new steady state is indicated in Table 1, accordingly, as being essentially the highest turning point of the front-loaded public investment path.

Since resource windfall is an initial one-period shock, the consumption tax rate rises to finance public investment in the long run. In terms of welfare gain, which is measured as a percentage increase in consumption from the original pre-windfall steady state, the loose absorptive capacity constraint delivers the best outcome. Yet consumption is volatile in the first several years at $b = 0.1$ given the higher magnitude of overshooting public investment.

A temporary FDI shock hits the economy in Figure 1, which shows different absorptive capacity constraints and their respective optimal rates of public capital increase according to Table 1. In response to the shock, a resource output-to-GDP ratio doubles to 18 percent, and resource revenues rise to 14 percent of GDP during the next ten years. The saving share of resource revenues ϕ_t, though quite small, generates a large increase of external savings in the SWF. A dotted line depicts the lowest increase of public capital associated with the tight absorptive capacity constraint, and therefore an excess of resource windfall is saved more in the SWF rather than invested domestically. A dashed line corresponds to the dynamics under $b = 0.2$ as the middle case. A solid line, related to the loose absorptive capacity constraint and thus high accumulation of public capital, shows the welfare preferred case, as it delivers permanently higher consumption and permanently lower labor (higher leisure) than the other two lines.

Figure 1: **Optimal rate of public capital increase at given absorptive capacity constraint**

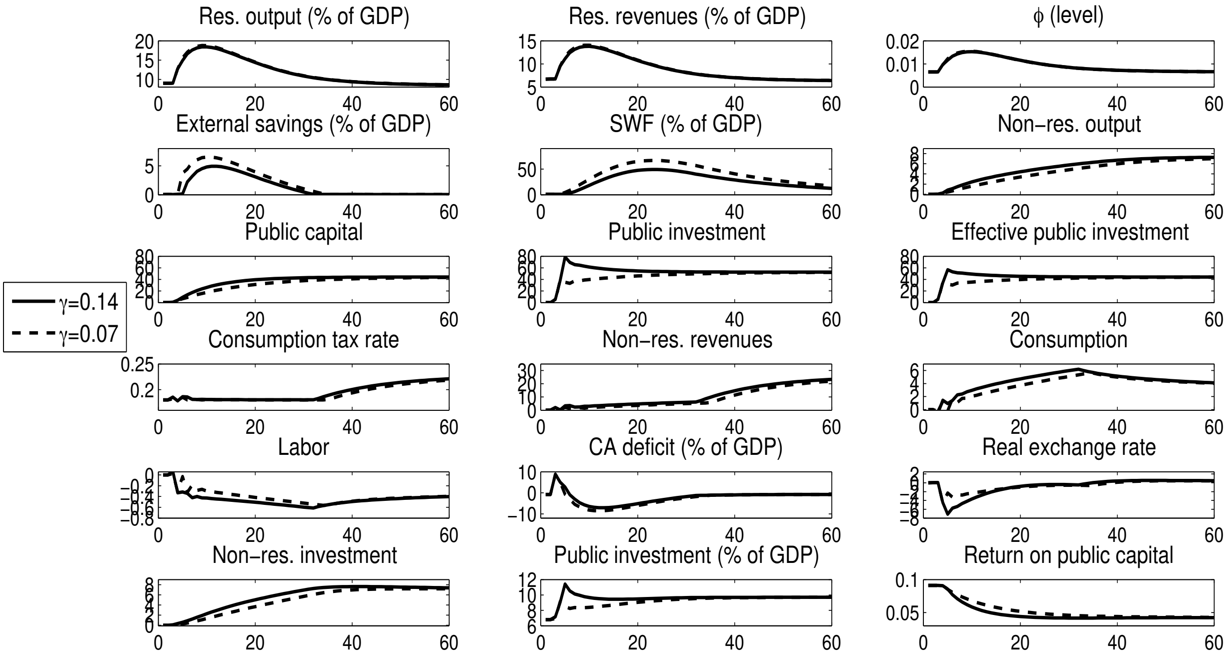


Y-axis is in percent deviation from the initial steady state unless denoted otherwise. The looser the absorptive capacity constraint, the higher the public capital rise.

In Figure 1, consumption tax rate as a part of non-resource revenues increases in the later period, since external savings eventually deplete to maintain public investment. Current account deficit initially rises due to the temporal FDI shock but then declines, as resource output and savings in the SWF expand. The magnitude of public capital increase affects the extent of exchange rate appreciation: the more the government invests, the more the exchange rate appreciates. Return on public capital, meanwhile, depends on its availability: capital scarcity generates its higher return and vice versa (the dotted line versus the solid line in Figure 1). Figure 2 compares the impulse-response functions across two adjustment speeds at $b = 0.2$. A solid line illustrates the optimal front-loaded public investment path ($\gamma = 0.14$), while a dashed line shows no overshooting dynamics relative to a new steady state ($\gamma = 0.07$). Consumption and labor under non-optimal public investment appear to be more volatile than they are under the front-loaded policy. In terms of welfare gain, the optimal public investment policy is equivalent to a 2.5 percent increase in consumption from the original pre-windfall steady state, while the non-overshooting path at $\gamma = 0.07$ produces a welfare gain of 1.9 percent.

This finding suggests that the front-loaded public investment policy should be preferred by resource abundant low-income countries, supporting essentially Alter et al. (2017). Despite public investment inefficiency and limited capacity to absorb well public investment, still temporal resource windfalls should be invested in accumulation of public capital early on. There is

Figure 2: **Different adjustment speed**



Y-axis is in percent deviation from the initial steady state unless denoted otherwise.

a need to expand the domestic capacity; "investing to invest" for raising home-grown capital and the building of infrastructure network are very relevant in developing economies. Maintenance expenditures may also increase to improve the quality of existing infrastructure, thereby reducing production costs and spurring economic growth. Moreover, if according to Gupta et al. (2014) the stock of effective public capital is low and accumulates slower than suggested by government spending on investment, then the front-loaded public investment is plausible to pursue an early accumulation of effective public capital.

5 Sensitivity analysis

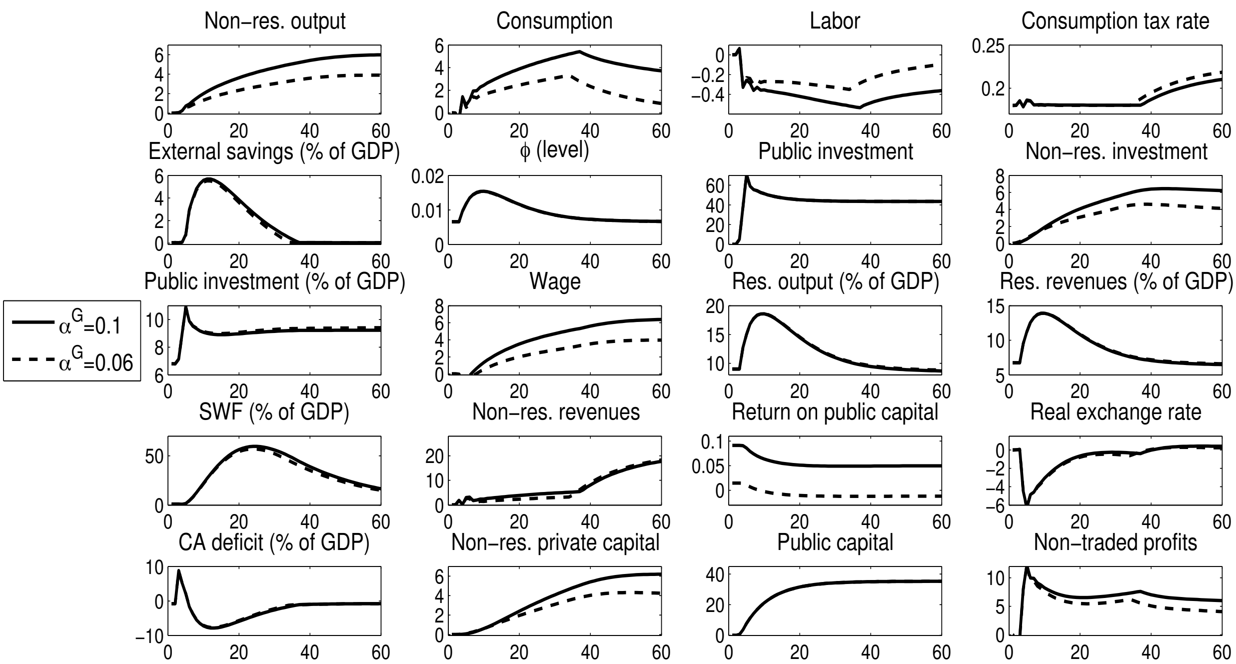
This section examines two cases. Public capital is less productive compared to the baseline model, and there is no resource windfall in the first place. If public capital has its output elasticity of $\alpha^G = 0.06$, as opposed to the baseline $\alpha^G = 0.1$, and its return is therefore lower than the SWF's interest rate by 1.23 percentage point, then the government should accumulate less capital but at a faster adjustment speed (see Table 2). This is because over time the return on public capital decreases as capital is expanded by public investment; thus, the front-loaded public investment path is still preferred. However, relatively volatile consumption takes place at the tight absorptive capacity constraint $b = 0.3$ as opposed to $b = 0.1$ in Table 2. This is because public capital, being less productive, does not need to increase much at a new steady state but should adjust to that level fast.

Table 2. **Sensitivity analysis:** $\alpha^G = 0.06$	$b = 0.1$	$b = 0.2$	$b = 0.3$
Optimal increase of public capital	26.1%	20.36%	16.06%
Optimal adjustment speed	0.29	0.28	0.28
Optimal increase of public investment at new SS	27%	21.5%	17.1%
Overshooting magnitude of public investment	59.3%	45.7%	38.4%
Overshooting magnitude of effective public investment	53.7%	39.6%	32.3%
Consumption tax rate increase at new SS	16.3%	13%	10.3%
St dev of consumption growth over first 10 years	0.84	0.91	0.98
Welfare gain w.r.t. original pre-windfall steady state	1.1%	0.9%	0.8%

The tightness of absorptive capacity constraints b in the equation (19) is varied across 0.1, 0.2, and 0.3.

Figure 3 contrasts the dynamics of a public capital increase by 35.32 percent at $b = 0.3$, according to Table 1, versus its behavior under a reduced output elasticity, $\alpha^G = 0.06$. A solid line shows that relatively productive public capital generates higher non-resource output, consumption, and wages, since labor also becomes productive allowing households to have more leisure. However, consumption tax rate is higher in the long run under $\alpha^G = 0.06$, because more tax revenues are needed to finance the same level of public investment, as low output due to less productive public capital creates fewer fiscal revenues. In order to compare the main

Figure 3: **Different output elasticity of public capital**



Y-axis is in percent deviation from the initial steady state unless denoted otherwise.

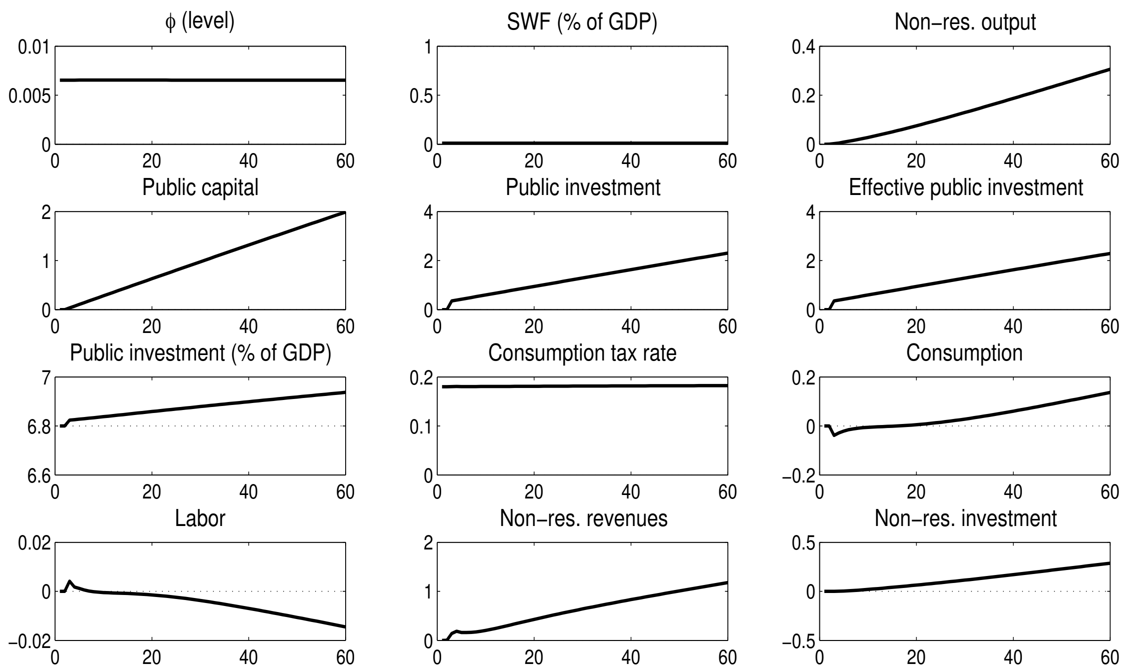
results with a scenario of no initial resource windfall, a version of zero FDI shock is simulated within the same framework. Table 3 summarizes the results without a resource windfall across different absorptive capacity constraints. The percentage increase of public capital is the same as in the baseline version with FDI shock, but the adjustment speed is significantly lower suggesting a gradual increase of public investment, instead of its earlier front-loaded path, due to the absence of initial resource windfall.

Table 3. **No resource windfall:** $\alpha^G = 0.1$, $\beta = 0.91$	$b = 0.1$	$b = 0.2$	$b = 0.3$
Optimal increase of public capital	64.74%	44.15%	35.32%
Optimal adjustment speed	0.001	0.001	0.001
Optimal increase of public investment at new SS	41%	28.4%	23%
Consumption tax rate increase at new SS	20.7%	14.3%	11.6%
St dev of consumption growth over first 10 years	0.024	0.017	0.014
Welfare gain w.r.t. original steady state	-0.01%	-0.001%	-0.003%

The tightness of absorptive capacity constraints b in the equation (19) is varied across 0.1, 0.2, and 0.3.

Negative numbers for welfare gain mean that a scenario of no resource windfall is worse than the original steady state without any increase of public capital. This is due to the absence of external savings as an additional fiscal buffer to finance public investment, and the only instrument is consumption tax, which is distortionary for the welfare contributing consumption component. Figure 4 shows the dynamics of public capital increase by 35.32 percent at $b = 0.3$

Figure 4: **Dynamics under no resource windfall**



Y-axis is in percent deviation from the initial steady state unless denoted otherwise.

with its adjustment speed of 0.001. The saving share of resource revenues ϕ_t is at its constant calibrated value, while the SWF is zero. The gradual scaling-up of public investment is financed by a steady increase of consumption tax rate, which reduces consumption in the beginning and thus not welfare improving.

Table 4. **No resource windfall:** $\alpha^G = 0.1$, $\beta = 0.98$	$b = 0.1$	$b = 0.2$	$b = 0.3$
Optimal increase of public capital	64.74%	44.15%	35.32%
Optimal adjustment speed	0.019	0.024	0.024
Optimal increase of public investment at new SS	74.4%	52.6%	43.4%
Consumption tax rate increase at new SS	40.6%	28.75%	23.9%
St dev of consumption growth over first 10 years	0.44	0.38	0.31
Welfare gain w.r.t. original steady state	-0.51%	-0.42%	-0.35%

The tightness of absorptive capacity constraints b in the equation (19) is varied across 0.1, 0.2, and 0.3.

Table 4 is produced at a higher discount factor $\beta = 0.98$ than the baseline one $\beta = 0.91$ which corresponds to a real interest rate of 2 percent on the government bonds, as opposed to the baseline 10 percent. The high discount factor, in general, implies that households are patient and value the future more than impatient households do with their low discount factor. In this model, the former case gives a higher optimal increase of public investment in Table 4 relative to Table 3. The more households are patient, the less government has its interest costs on the bonds; thus, the government can increase public investment to keep its budget balanced at steady state. However, since there is no resource windfall, consumption tax rises to finance the increased public investment, causing more a fall in welfare gain. In other words, under no resource windfall, the economy is worse off than in its initial steady state without any public investment, suggesting that it matters how fiscal expenditures are financed. If there is a resource windfall fortunately, then commodity-rich economies can benefit and improve their welfare by investing returns from their natural resources domestically, using the front-loaded public investment policy.

6 Conclusion

This paper examines the optimal fiscal policy to accumulate public capital through investing resource revenues domestically rather than saving them abroad in the SWF of resource-rich low-income countries. The model is the modified version of Berg et al. (2013) in several respects: The fiscal policy rule is expressed in terms of public capital as a stock variable, and the public investment path is obtained from the capital. The tightness of absorptive capacity constraints is captured by a single parameter b in the equation for effective public investment. External saving is a clearing fiscal instrument rather than distortionary consumption tax. There is a variable share of resource revenues saved in the SWF, as opposed to its fixed share, and the natural resource sector is capital-intensive with its FDI shock.

This study finds the optimal level of public capital and its adjustment speed to that new increased steady state. The associated optimal public investment path is front-loaded regardless of absorptive capacity constraints and productivity of public capital. Less productive public capital suggests the lower magnitude of increase for capital and public investment but should move at a faster adjustment speed to its new steady state level. The gradual non-overshooting increase of public investment causes consumption volatility and is not preferred under a no resource windfall either, since consumption tax becomes the only source for financing fiscal expenditures within this model. To conclude, resource-rich low-income countries can significantly gain from their commodity blessing by prudent public investment policy.

References

Agenor, P-R. (2009) 'Infrastructure Investment and Maintenance Expenditure: Optimal Allocation Rules in a Growing Economy', *Journal of Public Economic Theory*, 11(2): 233–250.

Agenor, P-R. (2010) 'A Theory of Infrastructure-Led Development', *Journal of Economic Dynamics and Control*, 34: 932-950.

Agenor, P-R. (2016) 'Optimal Fiscal Management of Commodity Price Shocks', *Journal of Development Economics*, 122: 183–196.

Akitoby, B., Coorey, S. (2012) *Oil Wealth in Central Africa: Policy for Inclusive Growth.* Washington, DC: International Monetary Fund, 1-247.

Alter, A., Ghilardi, M. F., Hakura, D. S. (2017) 'Public Investment in a Developing Country Facing Natural Resource Depletion', *Journal of African Economies*, 26 (3): 295-321.

Andersen, J. J., Aslaksen, S. (2008) 'Constitutions and the Resource Curse', *Journal of Development Economics*, 87: 227–246.

Berg, A., Portillo, R., Yang, S-C. S., Zanna, L-F. (2013) 'Public Investment in Resource-Abundant Developing Countries', *IMF Economic Review*, 61 (1): 92-129.

Boschini, A. D., Pettersson, J., Roine, J. (2007) 'Resource Curse or Not: A Question of Appropriability', *Scandinavian Journal of Economics*, 109 (3): 593–617.

Calderon, C., Serven, L. (2010) 'Infrastructure and Economic Development in Sub-Saharan Africa', *Journal of African Economies*, 19 (suppl-1): i13–i87.

Collier, P., van der Ploeg, R., Spence, M., Venables, A. J. (2010) 'Managing Resource Revenues in Developing Economies', *IMF Staff Papers*, 57 (1): 84-118.

Corden, W. M., Neary, J. P. (1982) 'Booming Sector and De-Industrialisation in a Small Open Economy', *Economic Journal*, 92: 825-848.

Delechat, C., Yang, S-C. S., Clark, W., Gupta, P., Kabedi-Mbuyi, M., Koulet-Vickot, M., Macario, C., Orav, T., Rosales, M., Tapsoba, R., Zhdankin, D. (2017) 'Harnessing Resource Wealth for Inclusive Growth in Fragile Western African States', *Journal of African Economies*, 26 (2): 256–293.

Gupta, S., Kangur, A., Papageogiou, C., Wane, A. (2014) 'Efficiency-Adjusted Public Capital and Growth', *World Development*, 57: 164–178.

Li, B. G., Gupta, P., Yu, J. (2017) 'From Natural Resource Boom to Sustainable Economic Growth: Lessons from Mongolia', *International Economics*, 151: 7-25.

Mehlum, H., Moene, K., Torvik, R. (2006) 'Institutions and the Resource Curse', *Economic Journal*, 116: 1–20.

Melina, G., Yang, S-C. S., Zanna, L-F. (2016) 'Debt Sustainability, Public Investment, and Natural Resources in Developing Countries: The DIGNAR Model', *Economic Modelling*, 52: 630-649.

Pritchett, L. (2000) 'The Tyranny of Concepts: CUDIE (Cumulated, Depreciated, Investment Effort) is Not Capital', *Journal of Economic Growth*, 5 (4): 361-384.

Richmond, C., Yackovlev, I., Yang, S-C. S. (2015) 'Investing Volatile Resource Revenues in Capital-Scarce Economies', *Pacific Economic Review*, 20 (1): 193-221.

van den Bremer, T. S., van der Ploeg, F. (2013) 'Managing and Harnessing Volatile Oil Windfalls', *IMF Economic Review*, 61 (1): 130-167.

van der Ploeg, F. (2011) 'Natural Resources: Curse or Blessing?', *Journal of Economic Literature*, 49 (2): 366-420.

van der Ploeg, F. (2012) 'Bottlenecks in Ramping Up Public Investment', *International Tax Public Finance*, 19: 509–538.

van der Ploeg, F., Venables, A. J. (2011) 'Harnessing Windfall Revenues: Optimal Policies for Resource-Rich Developing Economies', *Economic Journal*, 121 (551): 1-30.

van der Ploeg, F., Venables, A. J. (2012) 'Natural Resource Wealth: The Challenge of Managing a Windfall', *Annual Review of Economics*, 4: 315-337.

van Wijnbergen, S. (1984) 'The 'Dutch Disease': A Disease after All?', *Economic Journal*, 94 (373): 41-55.

Yogo, U. T., Verdier-Chouchane, A. (2015) 'Enhancing North Africa's Infrastructure for Improved Competitiveness', *African Development Review*, 27 (3): 274-287.

Appendix A: Parameter Values

Parameter	Definition
$\beta = 0.909$	discount factor
$\sigma = 2$	inverse of intertemporal elasticity of substitution for consumption
$\psi = 10$	inverse of Frisch elasticity of labor supply
$\varphi = 0.5$	home-bias in private consumption
$\nu = 0.6$	home-bias in government purchases
$\nu_g = 0.5$	home-bias in government purchases above the initial steady state
$\chi = 0.44$	elasticity of substitution between T and N goods
$\rho = 1$	elasticity of substitution between two types of labor
$\alpha^T = 0.65$	labor income share in traded sector
$\alpha^N = 0.45$	labor income share in non-traded sector
$\alpha^G = 0.1$	output elasticity of public capital
$\alpha^o = 0.9$	resource capital income share
$d, \rho_{zT} = 0.1$	learning-by-doing externalities
$\kappa^T, \kappa^N = 25$	investment adjustment cost in T and N sectors
$\delta^T, \delta^N, \delta^g, \delta^o = 0.1$	depreciation rates for K^T, K^N, K^G, and K^o
$\epsilon = 0.7$	public investment efficiency
$\iota^{div} = 0.4$	share of resource dividends accrued to the government
$\tau^c = 0.18$	consumption tax rate
$\tau^l = 0.08$	labor tax rate
$\tau^o = 0.58$	resource royalty rate
$r^* = 0.027$	real interest rate of SWF
$b = 0.1, 0.2, 0.3$	tightness of absorptive capacity constraint
$\phi = 0.0065$	constant share of resource revenues in external savings
$\rho_{FDI} = 0.8$	persistence in the FDI process
$\sigma_{FDI} = 6.26$	standard deviation of FDI shock
$\rho_{swf} = 0.956$	persistence in the SWF process
$\frac{C}{GDP} = 57.2\%$	consumption in percent of GDP
$\frac{C^T}{GDP} = 28.6\%$	consumption of traded goods in percent of GDP
$\frac{I}{GDP} = 17\%$	investment in percent of GDP
$\frac{Y^o}{GDP} = 9\%$	resource output in percent of GDP
$\frac{G^C}{GDP} = 13.3\%$	public consumption in percent of GDP
$\frac{G^I}{GDP} = 6.8\%$	public investment in percent of GDP
$\frac{G^T}{GDP} = 8.04\%$	government purchases of traded goods in percent of GDP
$\frac{EX}{GDP} = 21.6\%$	exports in percent of GDP
$\frac{B}{GDP} = 11.6\%$	public debt in percent of GDP
$\frac{SWF^*}{GDP} = 1\%$	SWF in percent of GDP