WP/13/xx

IMF Working Paper

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INTERNATIONAL MONETARY FUND

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IMF Working Paper

African Department and Research Department

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February 2013

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Abstract

Natural resource revenues are an increasingly important financing source for public investment in many developing economies. Investing volatile resource revenues, however, subjects an economy to macroeconomic instability. This paper applies to Angola the fiscal framework developed in Berg et al. (forthcoming) that incorporates investment inefficiency and absorptive capacity constraints, often encountered in developing countries. The sustainable investing approach, which combines a stable fiscal regime with external savings, can convert resource wealth to development gains while maintaining economic stability. Stochastic simulations demonstrate how the framework can be used to inform allocations between capital spending and external savings in facing uncertain oil revenues. An overly aggressive scaling-up path could render insufficient fiscal buffer. Consequently, negative oil shocks can interrupt investment progress and drive up the capital depreciation rate, disturbing economic stability and lowering the growth benefits of public investment.

JEL Classification Numbers: Q32, E22, F43, O41
Keywords: Angola, natural resource, public investment, resource-rich developing countries, DSGE models
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* We thank Andrew Berg, Dhaneshwar Ghura, Mauro Mecagni, Catherine Pattillo, and Mauricio Villafuerte for helpful comments. This working paper is part of a research project on macroeconomic policy in low-income countries supported by U.K.'s Department for International Development. All views and errors are the authors'.

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I. INTRODUCTION

Angola emerged from more than four decades of war to become Africa's second largest oil exporter and third largest economy. The civil war, which ended in 2002, decimated infrastructure, weakened institutions and slowed economic growth. In the decade since, real growth averaged more than 10 percent a year and Angola made progress on a variety of fronts, yet it ranks only 148 out of 187 countries on the Human Development Index (United Nations Development Programme (2011)) and scores 3 out of 6 on the Country Policy and Institutional Assessment's (CPIA) fiscal policy rating (World Bank (2011)).[1] While Angola is a middle-income country,[2] its physical and human capital needs more closely resemble those of a low-income country. The combination of its significant oil wealth and infrastructure gaps underscores the challenges faced by capital-scarce developing countries like Angola. This paper proposes a fiscal framework for investing volatile oil revenue in Angola.

The global financial crisis of 2008 precipitated a drop in world oil prices and led Angola to reassess its natural resource management. During the oil price boom of 2003-08 Angola began to rebuild infrastructure, both oil and non-oil sectors grew substantially, and per capita GDP reached middle-income levels. However, by 2008 expansionary fiscal and monetary policies and an overvalued exchange rate had left the country vulnerable. In the early years of the boom, Angola saved about 60 percent of the incremental increase in oil revenue, but as oil prices stayed up, leading to the belief that they were permanent, spending increased sharply. From 2006 to 2008, Angola spent 140 percent of its additional oil revenue, more than most other low- and middle-income oil producers.

By 2009, Angola faced growing macroeconomic instability against a backdrop of significant downside risks. International reserves fell by one-third in the first half of the year. The authorities' program, backed by the International Monetary Fund, sought to stabilize the economy in the short run through a combination of fiscal consolidation, an orderly exchange rate adjustment backed by tighter monetary policy, and measures to safeguard the financial sector.

Angola currently produces about 650 million barrels of oil a year, mainly offshore, and the volume is expected to increase over the medium term. Oil revenue comprised more than 75 percent of total revenue since 2002. It accrues to the government through two separate tax regimes: the tax and royalty regime that applies to Cabinda and onshore production, and production-sharing agreements that apply to newer contracts and are seen as more favorable to the government since Angola retains ownership of the oil and control of oil activities. Sonangol, the national oil company established in 1976, is the sole concessionaire for Angola's oil exploration and extraction, contributing about two-thirds of government oil revenue; the rest comes from taxes paid by private oil companies.

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[1]CPIA's fiscal policy rating assesses the short- and medium-term sustainability of fiscal policy and its impact on growth. Countries that have a rating 3 in 2011 include Afghanistan, Benin, Chad, and others.

[2]Angola's income per capita was over US$5,000 in 2011.

Turning resource wealth into development gains poses great challenges to policymakers. Given a long oil revenue horizon and the possibility of finding more reserves, the main challenge in Angola is to maintain macroeconomic stability and stable spending levels despite volatile oil revenue. Oil revenue is subject to volatility due to prices, production, and the institutional setting.[3] In a sample of 16 mainly low and lower-middle income oil producers (plus Gabon and Equatorial Guinea), oil revenue from 2002-2012 averaged 19.4 percent of GDP, with a standard deviation of 5.2 percent of GDP. Comparing to this sample average, the Angolan economy is more oil dependent than its peers and has experienced more revenue volatility. Since 2002, oil revenue in Angola averaged 33.3 percent of GDP, with a standard deviation of 6.2 percent of GDP. In 2011, oil production comprised 47.5 percent of GDP, and oil revenue surpassed 80 percent of total tax revenue.

The volatility of natural resource revenue can be damaging when investment is pro-cyclical, moving with revenue flows. Over-spending beyond absorptive capacity during a boom increases the costs of investment. Under-spending during a bust, on the other hand, may result in insufficient investment to maintain existing capital, driving up the depreciation rate and lowering the overall investment return. In addition, a fluctuating spending pattern can destabilize the domestic economy, as the recent boom-bust cycle experienced by Angola suggests.[4]

This paper applies the fiscal framework developed in Berg et al. (forthcoming) to Angola for investing volatile oil revenue. The analysis here compares the macroeconomic effects in Angola of continuing with the historical "spend-as-you-go" approach to fiscal policy versus adopting a "gradual scaling-up" approach, in line with the sustainable investing approach proposed in Berg et al. The gradual scaling-up analyzed for Angola combines a slowly increased investment path with external savings in a stabilization fund. By ramping up investment gradually, a stabilization fund can be shored up to provide a fiscal buffer and support a stable spending and tax regime. In addition to stability, this investing approach achieves capital sustainability, ensuring long-lasting growth benefits from investing resource revenue.

The discussion of the trade-offs between these two competing visions of fiscal policy is particularly germain given Angola's announced plans for the establishment of a sovereign wealth fund, the Fundo Soberano de Angola (FSDEA). While many details of the institutional framework for the FSDEA remain to be defined, there is a risk that it may subtract resources from the stabilization fund or result in its demise altogether.

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[3]In addition to fluctuating oil prices and production quantity, Angola also has recurrent problems of unpredictable transfers of oil revenues (the state oil company) to the treasury. The risk is that what is transferred is only what is left after Sonangol's financial operations. The authorities recognize that of these three sources of uncertainty the relationship between Sonangol and the central government is the only one fully under their control.

[4]Using data from mid-1980s to 2006, Pieschacon (2011) also finds evidence for Mexico that oil revenue volatility disturbed the domestic economy through the channel of spending policy that fluctuated with oil revenues.

If Angola chose to implement the gradual scaling-up approach, one practical question that would arise would be how to determine allocations between investment and a stabilization fund to build a fiscal buffer. A faster scaling-up pace may lead to quicker accumulation of public capital and higher non-resource growth. However, as more oil revenue is devoted to public investment, less can be saved, leaving the economy vulnerable to future negative shocks. Stochastic simulations that account for the historical volatility in oil prices can inform policymakers on allocation decisions in facing uncertain future oil revenues. When there is a non-trivial probability that a stabilization fund may be inadequate in maintaining a stable fiscal regime, the pace of the scaling-up should be reduced to ensure both fiscal and growth sustainability.

The framework is a dynamic stochastic general equilibrium (DSGE) model, which incorporates several features important for studying the macroeconomic effects of public investment in developing countries. These features include low investment efficiency and limited absorptive capacity, and an endogenous capital depreciation rate, which rises when insufficient public investment for maintenance. To capture the potential effects of Dutch disease due to excessive spending of foreign exchange, the model features learning-by-doing externalities in the non-oil tradables sector as in van Wijnbergen (1984) and Berg et al. (2010). Also, a wide range of oil prices are used to capture a high degree of uncertain oil revenue forecasts. The model abstracts from the nominal side of the economy and cannot analyze the short-run effects on policy shifts (including monetary and reserve policy) in response to higher oil revenue. Instead, it is a medium-term fiscal framework for managing resource revenue.

II. A Brief Literature Review

Conventional wisdom—following the successful Norway model—advises that resource revenue should be mostly saved in well-diversified portfolios of international financial assets, such as a sovereign wealth fund (e.g., Davis et al. (2001), Barnett and Ossowski (2003), and Bems and de Carvalho Filho (2011)). Since petroleum and mining reserves are non-renewable, the advice is in line with the permanent income hypothesis (PIH) that current spending out of a temporary increase in income should be minimal (Friedman (1957)).

Following the conventional PIH advice has the advantage of protecting resource-rich economies from the infamous natural resource curse.[5] It also can achieve intergenerational equity by preserving resource wealth for future generations. However, the narrow interpretation of the PIH—that resource revenue should be mainly saved in financial assets abroad—ignores the development needs of capital-scarce countries. Since future generations are likely to enjoy a higher standard of living irrespective of current resource wealth, the consumption share of resource wealth should be higher for the current poor generation than for future generations, as argued in Collier et al. (2010).

[5]The natural resource curse, widely studied in the literature (e.g., Gelb (1988), Sachs and Warner (2001), and Stevens (2003)), refers to the empirical findings that most resource-abundant countries tend to grow more slowly than their counterparts. See van der Ploeg (2011) for a survey.

The inappropriateness of the conventional PIH advice has been discussed extensively in the literature (e.g., UNCTAD Secretariat (2006), Sachs (2007), Collier et al. (2010), Baunsgaard et al. (2012), and International Monetary Fund (2012a)). Several papers also find theoretical support that public investment can dominate external saving as an optimal strategy to manage resource revenue in credit-constrained, capital-scarce economies (e.g., Takizawa et al. (2004), Venables (2010), van der Ploeg (2010a), van der Ploeg and Venables (2011), and Araujo et al. (2012)). Since public investment projects can potentially earn high returns in capital-scarce economies, it implies that adopting a fiscal framework predicated on a sovereign wealth fund as the savings mechanism can have a high opportunity cost in terms of foregone growth from more productive capital.

For highly resource-dependent economies with relatively large resource reserves, the main challenge of spending resource revenue is how to cope with revenue volatility. The sustainable investing approach proposed in Berg et al. (forthcoming) underscores the importance of building a fiscal buffer to sustain investment despite volatile revenue, as advised in Collier et al. (2010), van der Ploeg (2010b), Cherif and Hasanov (2012), and Van den Bremer and van der Ploeg (2012). Moreover, a sustainable investing approach underscores the importance of covering recurrent capital costs to sustain the growth benefits of investment. Productive public infrastructure is generally recognized to be important to speed up economic development. It is, however, often the case that politicians give preference to new capital investment instead of allocating sufficient budgetary resources for operating and maintaining the existing stock. Heller (1974, 1979) emphasizes that a predictables level of expenditure to cover recurrent capital costs is crucial to harness the productivity gains of capital investment. Following Rioja (2003), the model used here assumes that the depreciation rate of public capital rises with insufficient spending for maintenance and operation. This also captures stop-and-go types of scaling-up plans, which can lower returns to investment projects.

III. Model Description

The model is a small open, real economy that has three production sectors: non-traded goods, (non-oil) traded goods, and oil. Our analysis focuses on oil revenue financed (rather than debt-financed) investment scaling-ups, as intended by the Angola government. Given limited financial development in Angola, we assume that the private capital account is closed for simplicity.[6]

A. Households

A representative household chooses consumption c_t and labor l_t to maximize expected utility,

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{1}{1-\sigma} (c_t)^{1-\sigma} - \frac{\kappa}{1+\psi} (l_t)^{1+\psi} \right], \tag{1}$$

[6] The model description follows Berg et al. (forthcoming) closely.

subject to the budget constraint in units of domestic composite consumption:

$$(1+\tau_t^c)\,c_t + b_t = \left(1-\tau_t^l\right) w_t l_t + R_{t-1} b_{t-1} + \Omega_t^T + \Omega_t^N + s_t rm^* + z_t. \tag{2}$$

E_0 denotes the expectations operator conditional on information available at time 0. σ and ψ are the inverses of the elasticities of intertemporal substitution for consumption and labor supply, respectively. κ is the disutility weight on labor. w_t is a real wage index measured in units of consumption, τ_t^c and τ_t^l are the consumption and labor tax rates, rm^* denotes remittances in units of foreign consumption (denoted by $*$), and z_t denotes government transfers. s_t is the CPI-based real exchange rate, and Ω_t^T and Ω_t^N are profits from the traded and non-traded good sectors, respectively. The household holds domestic government bonds b_t, which pay $R_t b_t$ units of composite consumption at $t+1$, and R_t is the domestic gross real interest rate. Households do not have access to foreign loans.

Consumption c_t is a composite of non-traded goods (c_t^N) and traded goods (c_t^T), combined in a constant-elasticity-of-substitution (CES) basket

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

where χ denotes the intratemporal elasticity of substitution, and φ indicates the degree of consumption home bias. Let the composite consumption be the numeraire of the economy, and assume the law of one price holds for traded goods. Then, s_t is also the relative price of traded goods to composite consumption. The CES basket implies that the price of one unit of composite consumption is

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

where p_t^N is the relative price of non-traded goods to composite consumption.

1. Aggregate Labor and Wage Rates

Households only supply labor l_t^N and l_t^T to non-oil sectors. There is imperfect labor mobility as reflected by the following CES aggregator for total labor:

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

where δ is the share of labor in the non-traded sector in the initial steady state and $\rho > 0$ governs labor sectoral mobility. The real aggregate wage rate is then given by

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

B. Firms

Firms produce goods in either the non-traded goods sector (N) or the traded goods sector (T), using labor (l), private capital (k) and public capital (K^G). The production in the oil sector (O) is assumed to be exogenous, for simplicity.

1. Oil Sector

Oil output in the model follows an exogenous process:

$$\frac{y_t^O}{y^O} = \left(\frac{y_{t-1}^O}{y^O}\right)^{\rho_{yo}} e^{\varepsilon_t^{yo}}, \tag{7}$$

where $\rho_{yo} \leq 1$, $\varepsilon_t^{yo} \sim i.i.d.N(0, \sigma_{yo}^2)$ is the oil production shock and a variable without a time subscript represents its value in the initial steady state. We also assume that Angola's oil output is relatively small in the world market, and that the international commodity price p_t^{O*} (relative to foreign goods) is exogenous and follows the process

$$\frac{p_t^{O*}}{p^{O*}} = \left(\frac{p_{t-1}^{O*}}{p^{O*}}\right) e^{\varepsilon_t^{po}}, \tag{8}$$

where $\varepsilon_t^{po} \sim i.i.d.N(0, \sigma_{po}^2)$ is the oil price shock. We assume that the real oil price follows a random walk without a drift, as estimated by Hamilton (2009) using data from 1970 to 2008. Oil GDP in units of domestic composite consumption is

$$Y_t^O = s_t p_t^{O*} y_t^O. \tag{9}$$

The oil sector pays taxes based on a price dependent tax rate τ_t^O, which approximates the payoff of individual contracts at an aggregate level.

- $\tau_t^O = 0.56$, if $p_t^{O*} < \$75$;
- $\tau_t^O = 0.58$, if $\$75 \leq p_t^{O*} < \$100$;
- $\tau_t^O = 0.60$, if $\$100 \leq p_t^{O*} < \$125$;
- $\tau_t^O = 0.65$, if $p_t^{O*} \geq \$125$.

Oil revenue collected each period is

$$T_t^O = s_t \underbrace{\left(\tau^o p_t^{O*} y_t^O\right)}_{\equiv T_t^{O*}}. \tag{10}$$

As most oil output in Angola is exported, we assume that oil in the model is not consumed domestically.

2. Non-traded Good Sector

The non-traded sector is perfectly competitive. A representative firm uses the technology

$$y_t^N = z^N \left(k_{t-1}^N\right)^{1-\alpha^N} \left(l_t^N\right)^{\alpha^N} \left(K_{t-1}^G\right)^{\alpha^G}, \tag{11}$$

where α^G is the output elasticity with respect to public capital, and z^N is a productivity scale parameter.

Private capital evolves by the law of motion

$$k_t^N = \left(1-\delta^N\right) k_{t-1}^N + \left[1 - \frac{\kappa^N}{2}\left(\frac{i_t^N}{i_{t-1}^N} - 1\right)^2\right] i_t^N, \tag{12}$$

where $\kappa^N \geq 0$ is the investment adjustment cost parameter.

A representative non-traded good firm maximizes its net present-value profit weighted by the marginal utility of households (λ_t),

$$E_t \sum_{t=0}^{\infty} \beta^t \lambda_t \underbrace{\left[(1-\iota)\left(p_t^N y_t^N\right) - w_t^N l_t^N - i_t^N + \iota p_t^N Y_t^N\right]}_{\equiv \Omega_t^N \text{, profit of the non-traded good sector}}, \tag{13}$$

where ι captures distortions that discourage firms from investing and hiring further and Y_t^N denotes the aggregate output of non-traded goods. Implicitly, ι acts like a distorting tax on firms but revenue collected remains in the private sector. For simplicity, these implicit taxes are rebated back to the firms in a lump-sum fashion.

3. Traded Good Sector

The traded good sector is also perfectly competitive and produces by a similar technology to that in the non-traded sector

$$y_t^T = z_t^T \left(k_{t-1}^T\right)^{1-\alpha^T} \left(l_t^T\right)^{\alpha^T} \left(K_{t-1}^G\right)^{\alpha_G}. \tag{14}$$

The productivity z_t^T is subject to learning-by-doing externalities, depending on the last period traded output :

$$\ln z_t^T = \rho_{zT} \ln z_{t-1}^T + d \ln y_{t-1}^T. \tag{15}$$

Like the non-traded good sector, capital evolves according to

$$k_t^T = \left(1-\delta^T\right) k_{t-1}^T + \left[1 - \frac{\kappa^T}{2}\left(\frac{i_t^T}{i_{t-1}^T} - 1\right)^2\right] i_t^T, \tag{16}$$

and each firm maximizes its weighted preset-value profits,

$$E_t \sum_{t=0}^{\infty} \beta^t \lambda_t \underbrace{\left[\left(1-\iota\right) s_t y_t^T - w_t^T l_t^T - i_t^T + \iota s_t Y_t^T\right]}_{\equiv \Omega_t^T, \text{ profit of the traded good sector}}. \tag{17}$$

C. The Government

Let capital letters denote the aggregate level of a variable (e.g., C_t is aggregate private consumption). The flow government budget constraint is

$$T_t^O + \underbrace{\tau_t^c C_t + \tau_t^l w_t L_t}_{\equiv T_t^{NO}, \text{ non-oil tax}} + s_t\left(1+r^*\right) F_{t-1}^* = p_t^g G_t + Z_t + \left(R_{t-1} - 1\right) B + s_t F_t^*, \tag{18}$$

where F_t^* is the asset value of a stabilization fund earning a constant real interest rate r^*, G_t is government purchases with a relative price to composite consumption goods of p_t^g, and Z_t is aggregate transfers to households.

1. Investment Efficiency and Absorptive Capacity Constraints

Government purchases consist of expenditures on government consumption G_t^C and public investment G_t^I. We introduce the concept of *effective* public investment ($\tilde{G}_t^I$), which differs from the expenditure concept (G_t^I), by allowing for potential investment inefficiencies and absorptive capacity constraints. As a result, the law of motion of public capital is given by

$$K_t^G = (1-\delta_t^G) K_{t-1}^G + \underbrace{\epsilon_t\left(G_t^I\right) \times G_t^I}_{\equiv \tilde{G}_t^I, \text{ effective investment}}, \tag{19}$$

where δ_t^G is the time-varying depreciation rate of public capital, and $0 < \epsilon_t \leq 1$ governs the efficiency of public investment. To capture the idea that lack of maintenance shortens the life of existing capital, we model the depreciation rate as a decreasing function of investment expenditure:

$$\delta_t^G = \left\{ \begin{array}{ll} \delta^G \times \frac{\delta^G K_{t-1}^G}{\tilde{G}_t^I}, & \text{when } \tilde{G}_t^I < \delta^G K_{t-1}^G \\ \delta^G, & \text{when } \tilde{G}_t^I \geq \delta^G K_{t-1}^G \end{array} \right\}. \tag{20}$$

Based on the non-parametric estimation results by Arestoff and Hurlin (2006), we assume that investment efficiency takes two values: it falls from ϵ to $\bar{\epsilon}$ when the expenditure level rises above a threshold $\bar{G}^I$. This captures the idea of rising investment costs due to absorptive capacity constraints.[7] Specifically,

$$\epsilon_t\left(G_t^I\right) = \left\{ \begin{array}{ll} \epsilon, & \text{when } G_t^I < \bar{G}^I \\ \bar{\epsilon}, & \text{when } G_t^I \geq \bar{G}^I \end{array} \right\}. \tag{21}$$

Like private consumption, government purchases are a CES basket that includes traded and non-traded goods,

$$G_t = \left[\nu_t^{\frac{1}{\chi}}\left(G_t^N\right)^{\frac{\chi-1}{\chi}} + (1-\nu_t)^{\frac{1}{\chi}}\left(G_t^T\right)^{\frac{\chi-1}{\chi}}\right]^{\frac{\chi}{\chi-1}}, \tag{22}$$

where ν_t denotes the degree of home bias in government purchases. The relative price of government consumption to private consumption is

$$p_t^g = \left[\nu_t\left(p_t^N\right)^{(1-\chi)} + (1-\nu_t)\left(s_t\right)^{1-\chi}\right]^{\frac{1}{1-\chi}}. \tag{23}$$

Note that ν_t can be time-varying. In general, a large share of government purchases go to wage bills for paying public servants, implying a relatively high degree of home bias. Since our analysis focuses on allocating additional government spending to public investment, we allow the degree of home bias for additional government spending (ν_g) to be different from its steady-state value (ν). Hence,

$$\nu_t = \frac{\nu p^g G + \nu_g\left(p_t^g G_t - p^g G\right)}{p_t^g G_t}. \tag{24}$$

D. Fiscal Policy

The analysis considers two approaches to investing oil revenue. The first, "spend-as-you-go" approach, is intended to capture the macroeconomic effects of the absence of a medium-term fiscal framework—in essence an approach to fiscal policy similar to what Angola has practiced until now. This approach has government consumption, public investment, and transfers each period fluctuate with oil revenue income and builds little to no fiscal buffers over time. The second "gradual scaling-up" approach scales up public investment gradually and then sustains it at a higher level. With this approach, for a given path of public investment and government consumption, surplus revenue is saved in a stabilization fund (modeled after the cases of Chile and Colombia). Conversely, when there is a revenue shortfall, the fund is drawn down to maintain a level of investment commensurate with the given investment path. These two approaches are formalized as follows.

[7] Several other approaches exist to model absorptive capacity constraints. Buffie et al. (2012) model this as increasing "prices" of public investment. van der Ploeg (2012) models this as an internal adjustment cost linked to the public investment management index (PIMI, Dabla-Norris et al. (2011)).

- **The Spend-as-You-Go Approach.** With this approach, each period the government allocates a fixed share γ of additional oil revenues to public investment and government consumption. Transfers to households adjust to clear the government budget constraint. When oil revenue grows, government purchases and non-oil GDP also grow. The feedback effect of more government spending generates higher non-oil tax revenues, driving up transfers to households. As government consumption, public investment, and transfers all rise when oil revenue increases, it implies a procyclical policy stance on managing oil revenues.[8] Specifically,

$$p_t^g G_t^I - p^g G^I = \gamma \left(T_t^O - T^O \right) \tag{25}$$

and

$$p_t^g G_t^C - p^g G^C = (1-\gamma) \left(T_t^O - T^O \right). \tag{26}$$

External savings with the spend-as-you-go approach are set such that F_t^* is maintained at its initial low value: $F_t^* = F^* \; \forall \; t$. Throughout simulation horizon, the tax rates are fixed at leves in the the initial state.

- **The "Gradual Scaling-Up" Approach.** With this approach, the government plans a gradual scaling-up path of public investment and government consumption as a share of GDP: $\left\{ s_t^{GI} \right\}_{t=0}^{t=N}$ and $\left\{ s_t^{GC} \right\}_{t=0}^{t=N}$. Public investment is scaled up gradually despite the possibility of a revenue surge; the gradual pace makes it possible to build a stabilization buffer against future oil revenue shocks. When a stabilization fund is insufficient to continue the predetermined investment, investment expenditure for the period is reduced to keep a nonnegative value in the stabilization fund, which in the model implies that the government cannot borrow externally to finance public investment. Should negative oil shocks be unexpectedly large, it is assumed that investment spending in that period is reduced to the point where the value of the stabilization fund is non-negative. The non-negative constraint on a stabilization fund excludes the possibility that the government can borrow externally to finance the investment scaling-up. The stabilization fund evolves by

$$F_t^* = F_{t-1}^* + ES_t^*, \tag{27}$$

where ES_t^* is the external savings. From (18) and (27), it can be seen that external savings are the government budget balance:

$$ES_t = T_t^O + T_t^{NO} + s_t r^* F_{t-1}^* - p_t^g G_t - Z_t - (R_t - 1) B, \tag{28}$$

where $ES_t = s_t ES_t^*$. The above equation implies that the external saving rate of oil revenues each period is time varying and can be negative. For a given spending level, higher oil revenue implies a higher external saving rate. When oil revenues fall short of the government expenditure level, negative savings indicate that the stabilization fund

[8] Other designs of the spend-as-you-go approach can also be analyzed. For example, government consumption and transfers can be kept at the same shares of oil revenues in the initial state, and public investment adjusts to clear the budget.

is drawn down to support pre-determined spending levels. Throughout the simulation horizon, we assume that tax rates and transfers are fixed at the levels in the initial state.[9]

E. Some Market Clearing Conditions and Identities

The total demand for non-traded goods is

$$D_t^N = \varphi \left(C_t + I_t^N + I_t^T \right) + \nu (p_t^g)^{\chi} G_t. \tag{29}$$

The market clearing condition for non-traded goods is

$$Y_t^N = (p_t^N)^{-\chi} D_t^N. \tag{30}$$

The current account deficit (CA_t^d) can be expressed as

$$CA_t^d = (C_t + I_t + p_t^g G_t) - Y_t - s_t \left(r^* F_{t-1}^* + RM^* \right), \tag{31}$$

where $I_t = I_t^N + I_t^T$ is total private investment, and $Y_t = p_t^N Y_t^N + s_t Y_t^T + Y_t^O$ is real GDP. Finally, the balance of payment condition is

$$CA_t^d = s_t \left(F_{t-1}^* - F_t^* \right). \tag{32}$$

IV. Equilibrium, Solution Method, and Calibration

The equilibrium system of the model consists of optimality conditions (see Appendix II), the government budget constraint, fiscal policy, market clearing conditions, the balance of payment condition, and the processes of the exogenous shocks. The equilibrium system is log-linearized around the initial steady state of the economy and solved by Sims's (2001) method for linear rational expectations models.

The model is at the annual frequency. The starting point of the analysis is to calibrate an initial steady state, mostly based on 2011 Angola data. The simulation horizon is 2012 to 2030. Table 1 summarizes the calibration and some variables in the initial steady state. Most structural parameters are calibrated following those in Berg et al. (forthcoming). The discussion below focuses on the calibration specific to the Angola economy.

In the initial state, the oil sector is 47.5 percent of GDP, matching the oil GDP share in 2011. The oil price in the initial state, US$94 per barrel, is calibrated to the average of the 2011 actual price and the WEO forecast prices (World Economic Outlook database updated June

[9] The policy description of the gradual scaling-up approach appears that external savings fluctuate to close the budget gap. Since the model does not rule out the possibility that the state variable F_t^* can get on an explosive path, policy implementation in the model is accomplished indirectly by introducing a rule for the external saving rate ϕ_t. See Appendix I for technical details.

2012, International Monetary Fund (2012b)) from 2012 to 2017. The oil production in the initial state is set to 605.8 million barrels, the 2011 production level. Given an oil tax rate of 0.58, the model implies that oil revenue is 79 percent of total revenue. Since Angola has not engaged in much external saving from past oil revenues, the size of the stabilization fund in the initial state is very low, at 0.1 percent of GDP. Public investment in the initial state is 8.7 percent of GDP, the level in 2011. When pursuing the gradual scaling-up approach, public investment gradually reaches 15 percent of GDP in 2022. Under the spend-as-you-go approach, $\gamma = 0.6$ so 60 percent of oil revenues above the initial steady-state level goes to public investment, and 40 percent goes to government consumption.

To calibrate the parameters related to absorptive capacity constraints, we resort to the only empirical evidence we could locate in the literature. Using Mexican data from 1980 to 1994, Arestoff and Hurlin (2006) find that the coefficient of regressing public capital produced (or effective investment in our model) on investment expenditures falls from 0.5 to 0.35 when investment expenditures exceeds 1.6 times of the average level in the sample.[10] Thus, to calibrate (21), we set $\epsilon = 0.5$ and $\bar{\epsilon} = 0.35$, and $\bar{G}^I = 1.6 \times G^I$. This range of investment efficiency $(0.35 - 0.5)$ is in line with Pritchett's (2000) estimate for sub-Saharan countries with a linear specification between effective investment and investment expenditures.

We assume the annual depreciation rate of public capital to be 7 percent ($\delta^G = 0.07$), higher than the range of 2.5 to 4.3 percent used for developing countries in the literature (e.g. Hurlin and Arestoff (2010) and Gupta et al. (2011)). The 2-4 percent range is similar to the depreciation rate for government nonresidential structures in the U.S. (2-3 percent, Table C, Herman et al. (2003)). Since public capital also includes equipment (which has a much higher depreciation rate than structures and infrastructure), and lack of maintenance on public capital is common in developing countries (World Bank (1994)), a 7-percent depreciation rate may better reflect the actual depreciation speed of public capital in Angola.

For the elasticity of public capital, we calibrate the non-oil output elasticity of public capital (α^G) to be 0.2. Combined with an annual depreciation rate of 7 percent, this yields a net return to public capital of 10 percent.[11] Our assumption on the return to public capital is in line with several types of infrastructure in China in the early development stage. Bai and Qian (2010) estimate the return to various types of infrastructure in China, and obtain a rate of around 10 percent for transport, storage, and postal service in the early 1980s (their Figure 11) and also around 10 percent for railway systems in the early 1990s (their Figure 15). Comparing to the returns to some of the World Bank projects, our assumption is, however, modest.[12] External financial assets in the stabilization fund are calibrated to earn a real annual rate of 2.7 percent, based on the average real return of the Norwegian Government Pension Fund from 1997 to 2011 (Gros and Mayer (2012)).

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[10] Absorptive capacity constraints are likely to vary across countries. This suggests that when estimates based on Angola data are available, the model should be re-calibrated to better capture the constraint costs in Angola.

[11] The net return to public capital is defined as the marginal product of non-oil output less depreciation.

[12] International Bank for Reconstruction and Development and the World Bank (2010) reports that the median rate of return on World Bank projects in 2008 is about 24 percent in sub-Saharan Africa. However, there is also evidence pointing out that the output effect for World Bank lending projects is small (e.g., Kraay (2012)).

To calibrate the production distorting parameter (ι), the first-order condition of the firms' investment decision implies that $\iota = 0.21$ for a given deprecation rate of private capital ($\delta^N = \delta^T = 0.1$) and non-oil private investment share of GDP. Given the high oil dependence of the economic activity and a relatively small non-oil traded good sector, the Angola economy has relied on imports to a large extent to meet domestic demand, both private or public. For consumption and investment baskets, we assume $\varphi = 0.4$, less than the typical assumption of 0.5 in the literature. In addition, the degree of home bias in government purchases ($\nu = 0.4$) in the initial state is also much lower than the typical value assumed (> 0.5) for government purchases in other countries. For additional government spending, it is further assumed that the government relies heavily on imports ($\nu^G = 0.2$) to meet the goods and service demand to scale up public investment, as observed in the recent Angola experience.

Finally, to calibrate the process of oil production, we assume that oil productivity shocks are persistent with $\rho_{zo} = 0.9$. For a forecast of oil production, we back up oil productivity shocks (ε_t^{zo}) to hit the projected values of Y_t^O.[13] For the analysis under two oil price scenarios (Section V), we assume that from 2012 to 2017, the oil price will take the value of the forecast in the database of World Economic Outlook, International Monetary Fund (2012b). After 2017, it follows the process of (8), with the standard deviation of the oil price shock set to the historical value $\sigma^{po} = 0.1$.[14] For analysis that is based on a large number of simulations, oil prices are generated each period from a draw of oil price shocks from the estimated distribution (8).

V. SPEND-AS-YOU-GO VS. GRADUAL SCALING-UP

The analysis traces the macroeconomic dynamics under spend-as-you-go and gradual scaling-up approaches to investing oil revenue in Angola. It first explains the key differences between the two approaches using two scenarios of oil price forecasts. The baseline scenario assumes a less volatile path, and the alternative scenario assumes a period of large negative price shocks. Figure 1 contrasts the macroeconomic effects of the spend-as-you-go (dotted-dashed lines) with gradual scaling-up (solid lines) approaches in the baseline scenario, and Figure 2 presents the alternative scenario. Unless specified in parentheses, the figures are plotted in percent deviations from a growth path in absence of additional oil revenues from the 2011 level.

[13]This projection of oil production does not take into account any significant additional production capacity that may result from bringing pre-salt oil fields on stream.

[14]Using data real annual oil prices from 1980 to 2011 (the simple average of three spot prices: Dated Brent, West Texas Intermediate, and the Dubai Fateh) in logarithm, the process of (8) is estimated to have a standard deviation of 0.1 for the oil price shock.

A. Baseline Scenario

The oil price path from 2012 to 2017 in the baseline takes the WEO forecast (updated, June 2012), which has an average oil price of US$101.80 for 2012, followed by a gradual decline through 2017 to US$87.6. Starting in 2018, the scenario draws a price shock each period from an estimated distribution based on historical price data. Oil revenues increase over time because of relatively steady production, combined with a slightly declining projection of oil prices.

Figure 1 shows that spend-as-you-go fiscal policy is procyclical. Public investment moves in tandem with oil revenue, and the stabilization fund remains at about the initial low level. In comparison, gradual scaling-up fiscal policy is relatively stable. Public investment is gradually scaled up to 15 percent of GDP in 2022, and government consumption is held constant at 18 percent of GDP (lower than 19.5 percent in the initial state). After public investment reaches its permanent higher level, government spending (consumption and public investment) is maintained at a constant share of 33 percent of GDP. With the external savings accumulated over time, the economy builds a stabilization fund reaches 11.1 percent of GDP in 2018 and 14.0 percent of GDP at the end of 2030.

In general, spending oil revenue has a direct effect through higher demand pressure on domestic production. Since part of additional government spending raises demand in non-traded goods, it also raises the real wage rate in the non-traded sector and hence the general wage rate for the economy. Higher wages increase income, leading to higher private consumption and investment. The strength of this demand-side effect depends on the composition of government purchases in terms of traded and non-traded goods. In Angola, where most demand is met by imports, the demand-side effect is rather feeble.

In addition to the demand-side effect, there is also a supply-side effect because public capital is more productive. Since public capital is an input into private production, more public capital makes private inputs more productive, which in turn crowds in private investment and hence produces more non-oil GDP. Higher public capital also raises the marginal product of labor, inducing more labor supply. However, as households' income rises, positive wealth effects also discourage households from working harder. The net effect of higher government spending on labor is a small decline relative to the initial steady-state level.

From 2012 to 2018, non-oil GDP is slightly higher with spend-as-you-go, but after 2018 gradual scaling-up performs better. The relatively high oil revenues in early years lead to more government spending than with gradual scaling-up and hence a stronger demand-side effect. More public investment produces more productive public capital. With higher public and private capital (due to the crowding-in effect of private investment), the spend-as-you-go approach generates a boom along with more oil revenues. Later, as oil revenue declines, public investment also falls, lowering the build-up public capital relative to the gradual scaling-up path. On the other hand, steadily increased public investment as modeled by the gradual-scaling-up approach builds up more productive capital over time, and starting in 2019 the economy enjoys higher non-oil GDP than with the spend-as-you-go approach for most years.

As for Dutch disease effects, the real exchange rate appreciates (by more with the spend-as-you-go approach during beginning years) under the baseline scenario, which leads to an initial decline in traded goods production. However, as productive public capital gradually increases, productivity in the traded goods sector (as well as the non-traded goods sector) rises through learning-by-doing externalities, and Dutch disease is overcome through investing oil revenue in productive public capital, as discussed in Sachs (2007) and Berg et al. (2010).

Over the longer horizon, the economy under the gradual scaling-up approach largely outperforms the one under the spend-as-you-go approach. Aside form building a stabilization buffer, public capital under gradual scaling-up is 6.1 percentage points higher than under spend-as-you-go in 2030 (43.1 percent vs. 37.0 percent above the growth path without additional oil revenue). Non-oil GDP is also 1.6 percentage points higher in 2030 with gradual scaling-up (14.1 percent vs. 12.5 percent above the growth path without additional oil revenue). Notice that the depreciation rate under either approach remains at the initial steady state 7 percent. Although investment expenditures fluctuate with spend-as-you-go, the magnitude of fluctuation is relatively small, sufficient to replenish depreciated capital. As we will see later, the depreciation rate can rise due to large negative oil price shocks when public investment expenditures fall substantially with spend-as-you-go.

The moderate difference in non-oil GDP between the two approaches shown in Figure 1 gives an impression that the benefit of gradual scaling-up is small. Given the projection of a steady increase in oil revenues, the advantages of the gradual scaling-up approach are understated. To illustrate the benefits of investing with a fiscal buffer, we turn to an alternative (perhaps more realistic) scenario, where oil prices are hit unexpectedly by large negative shocks.

B. Alternative Scenario

The path of oil prices in the baseline is relatively non-volatile, which may be unrealistic. In the alternative scenario, we subject oil prices to large negative shocks from 2015 to 2017. Oil prices fall by 44 percent from US$91.6 in 2014 to US$51.7 in 2015, and then recover to US$78.0 in 2017. Starting 2018, oil prices are subject to the same realized shock values as in the baseline.

With a more volatile path of oil prices, the benefits delivered by gradual scaling-up become more discernible. Figure 2 shows that the unexpected drop in oil revenues in 2015 forces public investment to be reduced from 9.9 percent of GDP in 2014 to 5.6 percent in 2015. The abrupt decline results in too little investment spending to properly maintain existing capital. Consequently, the depreciation rate for existing capital rises from 0.07 in 2014 to 0.14 in 2015. In 2017, public capital is almost 15.6 percent below the path without additional oil revenue. As a result, non-oil GDP and private consumption fall below the growth path without additional oil revenue starting 2015.

In contrast to the dramatic fall in public investment with spend-as-you-go, gradual scaling-up manages to sustain public investment despite big negative shocks. Since public investment only scales up gradually from 2012 on and government consumption is controlled at 18 percent of GDP, by 2014 the stabilization fund reaches 8.0 percent of GDP. When the shock hits in 2015, the stabilization fund is drawn down to support continuous scaling-up without interruption. In the medium term, the economy applying the gradual-scaling-up approach substantially outperforms what would happen with spend-as-you-go in terms of public capital, private investment, private consumption, and non-oil GDP. In 2020, public capital, non-oil GDP, and private consumption are 11.1, 3.7, 2.1 percent above the path without additional oil revenue, compared to -13.1, -0.5, and -0.9 percent with spend-as-you-go, respectively.

With a stabilization buffer under the gradual scaling-up approach, Figure 2 shows that the economy also performs much better in the long run than the one without. At the end of 2030, public capital, non-oil GDP, private consumption are 30.6, 12.5, and 10.3 percent above the growth path with gradual scaling-up, compared to 15.2, 7.1, and 7.9 percent with spend-as-you-go, respectively.

C. Stabilization Effect of the Gradual Scaling-up Approach

Comparing Figure 1 to Figure 2, the stabilization effect of the gradual scaling-up approach is more discernible when oil prices are volatile. Table 2 compares coefficients of variation for key macroeconomic variables with the two approaches under the alternative scenario for the oil prices.[15]

Table 2 shows that public investment is 64 percent more volatile with spend-as-you-go than with gradual scaling up. Despite a smooth investment path, public investment with gradual investing can still experience some fluctuations. When large negative revenue shocks hit, the stabilization fund may not have sufficient balance to support a pre-determined investment level, forcing investment expenditures to dip and other macroeconomic variables to adjust. For private consumption, non-oil GDP, and private investment, the standard deviations are about $70 - 80$ percent bigger with spend-as-you-go than with gradual scaling-up. This result highlights the importance of the fiscal channel, through which volatile oil revenue substantially affects domestic stability if periodic government spending cannot be decoupled from oil revenue flows.

VI. Determining a Sustainable Investing Path

The simulation results in the previous section show that between the two investing approaches, gradual scaling-up can better manage with oil revenue volatility and on average deliver better growth outcomes, especially in the medium and long term. When following gradual scaling-up, one question that naturally arises is how to allocate resources between capital spending and external savings. More aggressive scaling-up may yield more economic

[15] The coefficients of variation reported are the normalized standard deviations in percent deviations of a variable from its path without additional oil revenue.

growth, but an economy without a fiscal buffer is prone to fluctuating government spending paths driven by volatile oil revenues.

To demonstrate how the fiscal framework can be used to advise investment scaling-up decisions, stochastic simulations that account for the historical volatility in oil prices are conducted. Figures 3 and 4 plot the one- and two-standard deviation (68 percent and 95 percent) confidence bands of key variables for two investment paths using the gradual scaling-up approach. For each simulation, we draw a sequence of price shocks $\{\varepsilon_t^{po}\}$ from the distribution (8). For simplicity, we assume that the path of oil production is the same across simulation.[16] The solid black lines are mean responses, and the solid blue (dotted) bands are the one (two) standard deviation bands. The left column—the conservative path—assumes that public investment and government consumption follow the path assumed earlier, with public investment rising slowly from 9.2 percent of GDP in 2012 to 15 percent in 2022. The right column assumes a more aggressive path: public investment quickly rises to from 9.2 percent of GDP in 2012 to 20 percent in 2016. Government consumption in either case is fixed at 18 percent of GDP throughout the simulation horizon.

The comparison of the two columns supports a few observations. First, the wide confidence bands for oil prices (from about \$50 to US\$150) underscore the volatility of oil prices and hence oil revenue flows. The uncertain revenue forecast implies a wide range of possible economic outcomes. This suggests that any macroeconomic forecast based on a specific path of oil revenue will be highly uncertain. The exercise assumes that the projected oil production quantity is not subject to uncertainty. The degree of volatility would be higher if volatility in oil production is also incorporated, which would certainly not be an unreasonable assumption given recent production difficulties in 2011.

Second, the two seemingly conflicting policy objectives of economic growth and stability can be dealt with if a proper balance between investing and external savings can be reached. With the conservative scaling-up plan (the left columns of Figures 3 and 4). The median size of the stabilization fund is 48.1 percent of GDP in 2025, with a 68 percent lower bound of 0.9 percent of GDP. The fund is sufficient to support the scaling-up path among roughly two thirds of the realized oil price paths. Even when the fund cannot fully support the scaling-up path, the reduction in public investment is relatively small. In 2025, the median (mean) public investment is maintained at targeted 15 (14.3) percent of GDP, and the 68-percent lower bound is 13.2 percent of GDP. Overall, the error bands of the public capital, especially the 68-percent ones, are quite narrow (the second left plot of Figure 4). Consequently less economic stability is sacrificed due to oil revenue volatility.

With the more aggressive scaling-up plan (the right columns), about 70 percent of the time the stabilization fund cannot fully support the intended scaling-up path. Median (mean) public investment in 2025 at 18.0 (16.2) percent is below the targeted 20 percent of GDP. While public capital can be higher (the mean is 37.4 percent above the growth path, vs. 34.6 with conservative scaling-up), it also runs much higher tail risks of accumulating less public capital. The 68 percent lower band is -5.2 percent with the aggressive path in 2025 vs. 25.6

[16] This means that the path of $\{\varepsilon_t^{yo}\}$ is the same across simulations.

percent with the conservative path. Similar to the outcome with spend-as-you-go, large swings in public investment and hence public capital induce great instability. As shown in Figure 4, the confidence bands are wider for non-oil GDP and private consumption under the aggressive path. The 68-percent bands for non-oil GDP (private consumption) range from 5.5 to 23.3 percent (3.9 to 15.6 percent) above the growth path in 2025, compared to 7.8 to 11.9 percent (5.5 to 12.2 percent) with the conservative path. Moreover, despite a more stable economy with the conservative scaling-up path, households on average enjoy only slightly more consumption as under the aggressive path. In 2025, the mean private consumption is 9.5 percent above the growth path with aggressive scaling-up vs. 8.8 percent with conservative scaling-up.

That a more aggressive scaling-up plan does not lead to better average economic outcomes may seem puzzling. When oil revenues are higher, it is true that a more aggressive path leads to higher and faster economic growth, mainly by expanding the stock of public capital. When negative shocks hit, the adverse impact of an insufficient buffer does more than suppress investment spending. The aggressive path, which does not have much buffer, cannot sustain investment even at a level to maintain existing capital. As a result, the depreciation rate can rise much higher under the aggressive scaling-up as shown in the top row of Figure 4. The 68-percent (95-percent) upper bound of the depreciation rate from 2012 to 2025 is averaged 0.08 (0.13) with the aggressive path, higher than 0.07 (0.09) with the conservative path. Thus, with aggressive scaling-up, public capital can fall quickly and substantially below the growth path, despite aggressive scaling-up efforts earlier. Like the spend-as-you-go approach analyzed earlier, the fluctuating investment path of more aggressive scaling-up lowers the return on earlier investment and hence undermines the growth effect of investing oil revenues.

The exercise on the stochastic simulations performed here suggests that the conservative investing path analyzed runs a much smaller risk of jeopardizing economic stability while achieving sustainable growth. The comparison of two scaling-up paths highlights the risks of scaling-up too fast. Similar analysis can be conducted on moving from the conservative path to an overly conservative scaling-up path. When scaling-up is slow and minimal, economic growth is also likely to be slow and minimal. Yet the stabilization fund could end up with an unnecessarily large buffer that earns a relatively low return at a high opportunity cost in economic growth.

VII. CONCLUSION

The recent economic turmoil in Angola offers resource-rich developing countries a valuable lesson about managing volatile oil revenue. Taking the spend-as-you-go approach forward could destabilize the economy and lead to the types of boom-bust cycles that many oil-dependent economies have suffered. This paper constructs a fiscal framework for managing Angola's oil revenue and proposes gradual scaling-up to achieve the policy objectives of both economic growth and stability.

Gradual scaling-up strikes a balance between promoting growth through investment and ensuring economic stability through a stabilization buffer. By scaling-up public investment slowly at first, this approach could allow a country with little buffer to shore up its stabilization fund and also mitigate any Dutch disease impact on traded goods production. As the public capital stock gradually increases, public investment as a share of GDP can continue at a higher level than in the beginning to ensure that the growth benefits from more public capital can be sustained.

The fiscal framework used in this analysis can also be used to inform decisions on investment and external savings. Stochastic simulations that account for the historical process of oil prices (and other important sources of volatility) can deliver a probabilistic assessment of stability risks and a range of macroeconomic outcomes for a given fiscal path. While over-investing leaves the economy vulnerable to volatility risks, under-investing can cause economic development to stagnate.

Finally, the scaling-up path analyzed here for Angola is only one example of the sustainable investing approach. For a country where absorptive capacity constraints are less of a concern (perhaps because of international collaboration in development projects) and oil flows are sufficiently high, public investment might be front-loaded so long as investment is sufficient after the frontloading stage to maintain public capital. For a country with a long revenue horizon like Angola, securing funding for maintaining a higher capital stock is less of an issue. But consideration should still be given to the critical bottlenecks in absorptive capacity that increase the direct costs of carry of external borrowing for a more accelerate scaling-up of investment spending. Further, for countries with a short revenue horizon, decisions about scaling-up magnitudes should be jointly considered with oil exploration in order to maintain public capital after oil reserves are exhausted.

Table 1. **Parameter Calibration**

parameters	values	notes
σ	2	inverse of intertemporal elasticity of substitution for consumption
ψ	10	inverse of Frisch elasticity of labor supply
φ	0.4	degree of home bias in consumption
χ	0.44	elasticity of substitution between traded and non-traded sectors
δ	0.565	share of labor supplied to non-traded sector
ρ	1	elasticity of substitution between the two types of labor
β	0.91	the discount factor
α^N	0.65	labor income share in non-traded good sector
α^T	0.45	labor income share in traded good sector
α^G	0.2	output elasticity of public capital
d, ρ_{ZT}	0.1	learning-by-doing externalities
ι	0.21	firms' production distortion parameter
κ^N, κ^T	25	investment adjustment cost
δ^N, δ^T	0.1	depreciation rate for K^N, K^T, and K^O
δ^G	0.07	depreciation rate for public capital
ϵ	0.5	efficiency of public investment
$\bar{\epsilon}$	0.35	absorptive capacity constraints
ν	0.4	home bias of government purchases
ν^G	0.2	home bias of government purchases above the level in initial state
τ^l	0.1	effective labor tax rates
τ^c	0.1	effective consumption tax rates
s^B	0.347	debt-to-GDP ratio in initial state
$\frac{G^C}{GDP}$	0.195	GC/GDP in initial state
$\frac{G^I}{GDP}$	0.087	GI/GDP in initial state
$\frac{T^O}{T}$	0.8	oil tax/tax in initial state
$\frac{sF^*}{GDP}$	0.001	stabilization fund/GDP in initial state
ρ_{yo}	0.9	AR(1) coefficient in oil productivity process
σ_{po}	0.1	standard deviation of oil price shock

Table 2. **Stabilization Effects with Gradual Scaling-up.** Coefficients of variation in percent deviations from the growth path under alternative scenario.

Variables	**Spend-as-You-Go**	**Gradual Scaling-up**
public investment	1.15	0.70
non-oil GDP	0.87	1.51
private consumption	0.81	1.35
private investment	0.93	1.64

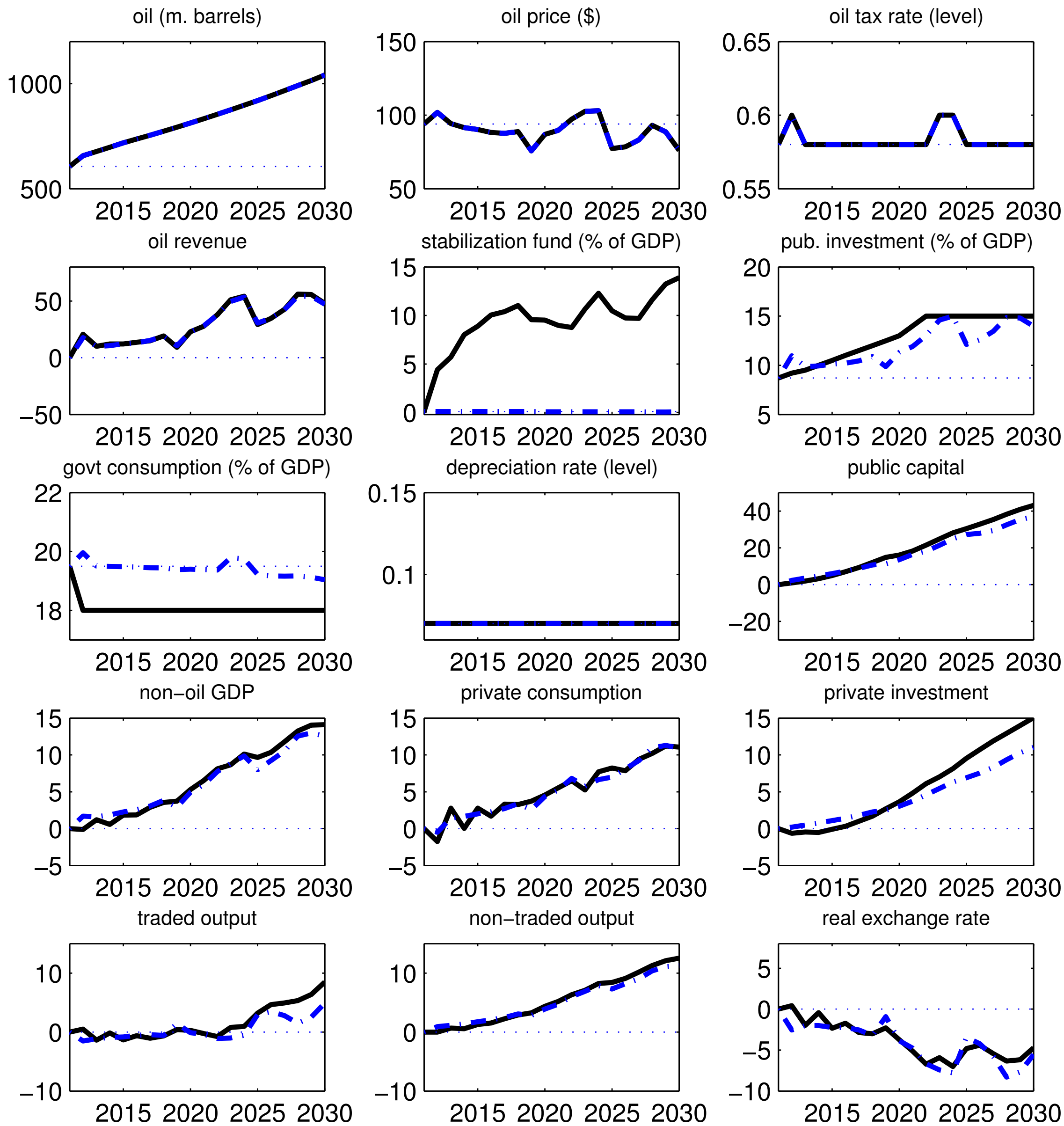

Figure 1. **Baseline Scenario**: The oil prices from 2012 to 2017 are taken from the WEO forecast (updated June, 2012). Dotted-dashed lines are with spend-as-you-go, and solid lines are with gradual scaling-up. The y-axis is in percent deviations from the growth path unless otherwise stated in parentheses. X-axis starts from 2011 (or the initial state).

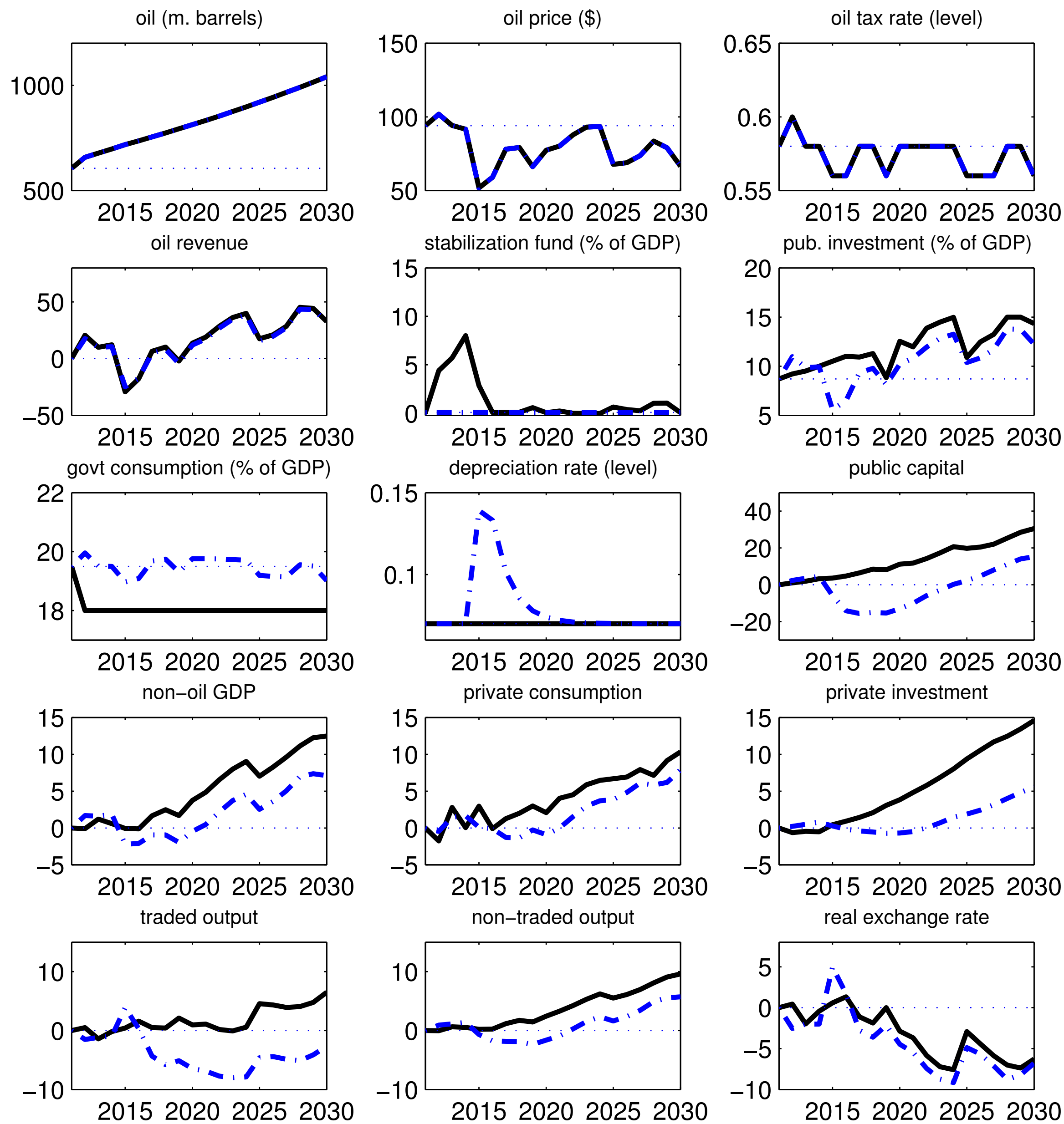

Figure 2. **Alternative Scenario**: Relative to the baseline, the oil price is subject to large negative shocks from 2015 to 2017. Dotted-dashed lines are with spend-as-you-go, and solid lines are with gradual scaling-up. The y-axis is in percent deviations from the growth path unless otherwise stated in parentheses. X-axis starts from 2011 (or the initial state).

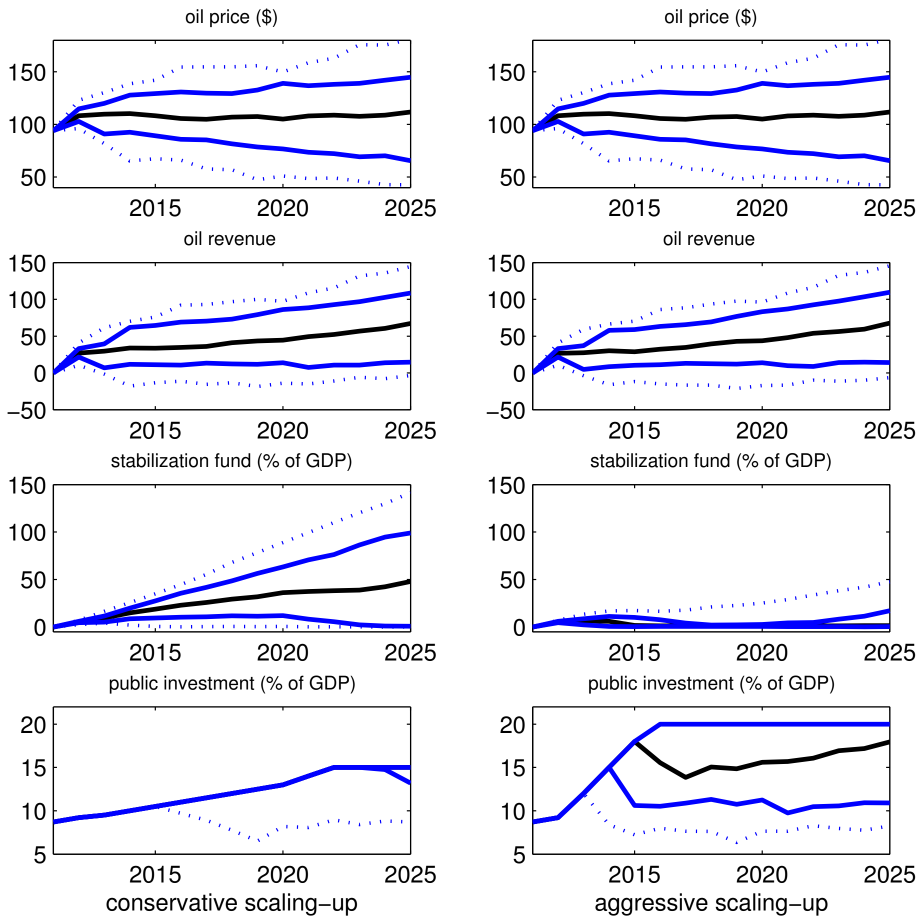

Figure 3. **Conservative vs. Aggressive Investing Scaling-up I.**: Error Bands are based on 100 oil price paths. Black solid lines are median responses; blue solid bands are 1-standard deviation confidence bands; dotted bands are 2-standard deviation intervals. The y-axis is in percent deviation from the growth path unless otherwise stated in parentheses.

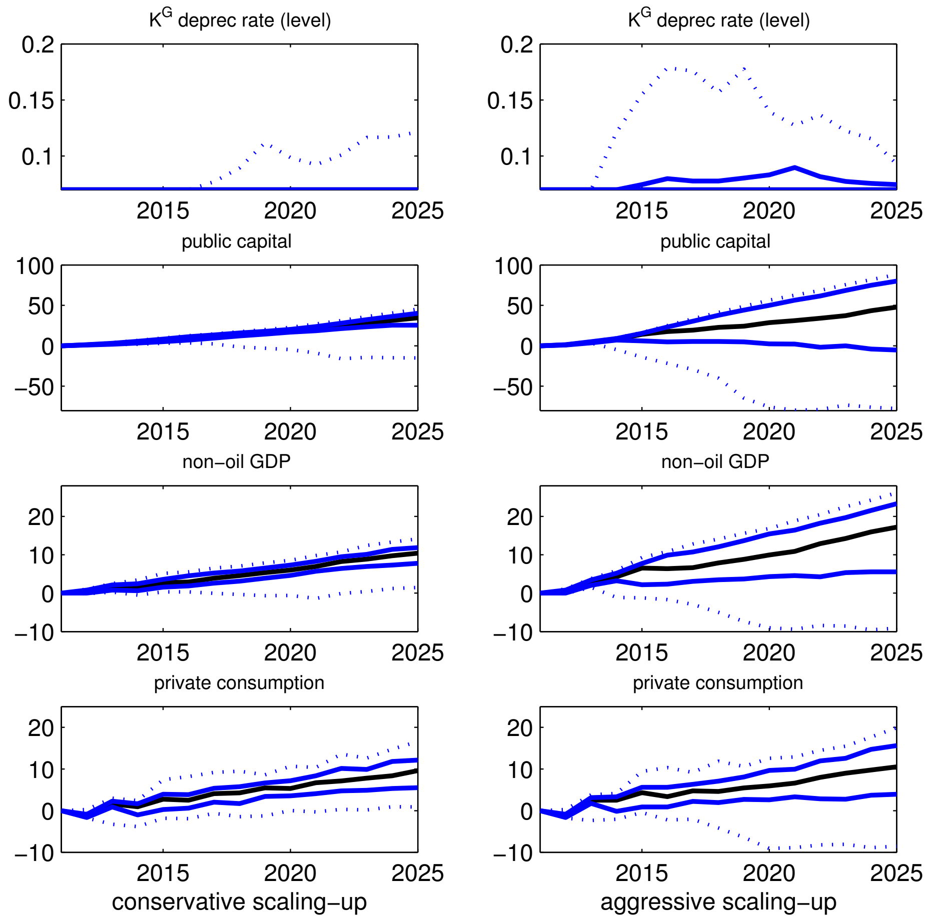

Figure 4. **Conservative vs. Aggressive Investing Scaling-up II.**: Error Bands are based on 100 oil price paths. Black solid lines are median responses; blue solid bands are 1-standard deviation confidence bands; dotted bands are 2-standard deviation intervals. The y-axis is in percent deviation from the growth path unless otherwise stated in parentheses.

APPENDIX I. IMPLEMENTING THE GRADUAL SCALING-UP APPROACH

The gradual scaling-up approach intends to have external savings as a residual to clear the government budget. Given a path of fiscal variables and oil revenues, the budget balance, if a surplus, is saved in a stabilization fund; if a deficit, it is financed by withdraws from the fund. This policy design is implementable in practice, but it encounters a technical complication as described in Section D.

To have external savings close the budget gap, a time-varying saving rate $\phi_t \equiv \frac{ES_t + p_t^g G_t^I}{T_t^O}$ and the revised definition for external savings $\tilde{ES}_t^*$ are introduced. Also, the law of motion of the stabilization fund is modified as

$$F_t^* = \rho_F F_{t-1}^* + \tilde{ES}_t^*, \tag{I.1}$$

where $\rho_F < 1$ is an arbitrary number close to 1 and $\rho_F = 0.95$.[17] The choice of ρ_F does not matter for the simulation outcome, because the lost value of the stabilization fund is re-captured in the revised external savings:

$$\tilde{ES}_t = T_t^O + T_t^{NO} + s_t \left[r^* + (1 - \rho_F) \right] F_{t-1}^* - p_t^g G_t - Z_t - (R_t - 1) B.^{18} \tag{I.2}$$

Implicitly, we assume that the government sets the saving rate according to the following rule:

$$\phi_t = \frac{1}{T_t^O} \left[T_t^O + T_t^{NO} + s r^* F^* - p_t^G G_t^C - Z - (R_{t-1} - 1) B \right] + \varepsilon_t^\phi. \tag{I.3}$$

where ε_t^ϕ is the shock to the saving rate. The objective is to solve for ϕ_t such that $Z_t = Z$, $\tau_t^l = \tau^l$, $\tau_t^c = \tau^c$, and $\left\{ s_t^{GI}, s_t^{GC} \right\}$ equal exogenously specified paths. We proceed by the following steps.

1. The model is first solved by the equilibrium system with (27) replaced by (I.1), (28) by (I.2), and adding (I.3) with $\varepsilon_t^\phi = 0$. The equilibrium solution yields the initial saving rate ϕ_t^0. Note that the initial savings rate is computed by setting $F_t^* = F^*$ and $Z_t = Z$ in order to yield an equilibrium solution.

2. Compute the size of $\left\{ \varepsilon_t^\phi \right\}$ to be injected each period based on $(Z_t - Z)$. For given fiscal paths—s_t^{GI}, s_t^{GC}, τ_t^l, τ_t^c—and ϕ_t^0, transfers are the technical residual to clear the government budget. At each period, $Z_t > Z$ ($Z_t < Z$) implies that external savings should be higher (lower) through injecting a positive (negative) saving rate shock ε_t^ϕ. A positive shock raises external savings thus reduces transfers to households.

[17] Introducing $\rho_F < 1$ allows to have non-zero external savings in the initial steady state. As the model is log-linearized, non-zero steady state values are required for the solution method to work.

[18] Comparing (28) to (I.2), the difference is $\tilde{ES}_t = ES_t + s_t (1 - \rho_F) F_{t-1}^*$. This modification for policy specifications does not alter the government budget constraint. To see this, using (I.1) in (I.2) yields (18).

3. After obtaining $\left\{\varepsilon_t^{\phi}\right\}$, the model is solved again, yielding a new fiscal adjustment path in transfers. Based on new $\{Z_t\}$, a new sequences of $\left\{\varepsilon_t^{\phi}\right\}$ are computed.
4. Iterate steps (2)-(3) until $Z_t - Z \approx 0$ for each period.

APPENDIX II. OPTIMALITY CONDITIONS

This appendix lists the first order conditions of all the optimization problems in the model. Let λ_t, λ_t^N, and λ_t^T be the Lagrangian multipliers for the maximization problems of households, non-traded firms, and traded firms. Define the Tobin's q as $q_t^N = \frac{\lambda_t^N}{\lambda_t}$ and $q_t^T = \frac{\lambda_t^T}{\lambda_t}$.

$$\lambda_t(1+\tau_t^c) = (c_t)^{-\sigma} \tag{II.1}$$

$$\lambda_t = \beta E_t\left(\lambda_{t+1} R_t\right) \tag{II.2}$$

$$\kappa\left(l_t\right)^{\psi} = \lambda_t\left(1-\tau_t^l\right) w_t \tag{II.3}$$

$$\lambda_t^N = \beta E_t\left\{\frac{\lambda_{t+1}}{\lambda_t}\left[\left(1-\delta^N\right)\lambda_{t+1}^N + \left(1-\alpha^N\right)(1-\iota)\, p_{t+1}^N \frac{y_{t+1}^N}{k_t^N}\right]\right\} \tag{II.4}$$

$$l_t^N = \delta\left(\frac{w_t^N}{w_t}\right)^{\rho} l_t; \quad l_t^T = \delta\left(\frac{w_t^T}{w_t}\right)^{\rho} l_t \tag{II.5}$$

$$\frac{1}{q_t^N} = 1 - \frac{\kappa^N}{2}\left(\frac{i_t^N}{i_{t-1}^N}-1\right)^2 - \kappa^N\left(\frac{i_t^N}{i_{t-1}^N}-1\right)\frac{i_t^N}{i_{t-1}^N} + \beta\kappa_N E_t\left\{\frac{q_{t+1}^N\lambda_{t+1}}{q_t^N\lambda_t}\left(\frac{i_{t+1}^N}{i_t^N}-1\right)\left(\frac{i_{t+1}^N}{i_t^N}\right)^2\right\} \tag{II.6}$$

$$l_t^N = \left[\frac{\alpha^N(1-\iota)\, p_t^N z^N\left(k_{t-1}^N\right)^{1-\alpha^N}\left(K_{t-1}^G\right)^{\alpha^G}}{w_t^T}\right]^{\frac{1}{1-\alpha^N}} \tag{II.7}$$

$$\lambda_t^T = \beta E_t\left\{\frac{\lambda_{t+1}}{\lambda_t}\left[\left(1-\delta^T\right)\lambda_{t+1}^T + \left(1-\alpha^T\right)(1-\iota)\, s_{t+1}\frac{y_{t+1}^T}{k_t^T}\right]\right\} \tag{II.8}$$

$$l_t^T = \left[\frac{\alpha^T (1-\iota) s_t z_t^T \left(k_{t-1}^T\right)^{\alpha^T} \left(K_{t-1}^G\right)^{\alpha^G}}{w_t^T} \right]^{\frac{1}{1-\alpha^T}} \tag{II.9}$$

$$\frac{1}{q_t^T} = 1 - \frac{\kappa^T}{2} \left(\frac{i_t^T}{i_{t-1}^T} - 1 \right)^2 - \kappa^T \left(\frac{i_t^T}{i_{t-1}^T} - 1 \right) \frac{i_t^T}{i_{t-1}^T} + \beta \kappa_T E_t \left\{ \frac{q_{t+1}^T \lambda_{t+1}}{q_t^T \lambda_t} \left(\frac{i_{t+1}^T}{i_t^T} - 1 \right) \left(\frac{i_{t+1}^T}{i_t^T} \right)^2 \right\} \tag{II.10}$$

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