

# Non-Renewable Resources, Fiscal Rules, and Human Capital

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## Abstract

This paper develops a multi-sector, small open economy Dynamic Stochastic General Equilibrium model, which includes the accumulation of human capital, built via public expenditures in education and health. Four possible fiscal rules are examined for total public investment in infrastructure, education, and health in the context of a sustainable resource fund: the spend-as-you-go, bird-in-hand spending; moderate front-loading, and permanent income hypothesis approaches. There are two dimensions to this exercise: the scaling effect, which describes the level of total investment, and the composition effect, which defines the structure of

investment between infrastructure, education, and health. The model is applied to Kenya. For impacts on the non-resource economy, efficiency of spending, and sustainability of fiscal outcomes, the analysis finds that, although investment frontloading would bring high growth in the short term, the permanent income hypothesis approach is overall more desirable when fiscal sustainability concerns are taken into consideration. Finally, a balanced composition is the preferred structure of investment, given the permanent income hypothesis allocation of total investment over time.

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# Non-Renewable Resources, Fiscal Rules, and Human Capital\*

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# 1 Introduction

There is growing emphasis on investing oil revenues domestically in oil-rich countries. During the oil price boom in 2000s, many oil rich countries began to break away from their traditional investment strategies, which focused on channeling the money back into financial systems of the advanced economies, and undertook ambitious domestic investment programs.<sup>1</sup> Despite the sharp decline in oil prices in recent years, the trend towards domestic investments seems to have gained momentum with anemic recovery and ever increasing economic and financial uncertainties in the advanced markets. For instance, the officials in the Kingdom of Saudi Arabia have recently announced publicly selling shares of the state oil giant, Saudi Aramco, and routing much of its worth, an estimated \$ 2 trillion, into a public investment fund.<sup>2</sup>

With persistently low interest rates in the aftermath of the global financial crisis, it may seem obvious that some of those domestic projects which were deemed not desirable before may become attractive. Notwithstanding the immediate appeal of such arguments, however, is the fact that policy makers, who are to act on behalf of all constituents in their jurisdictions, typically operate with complex objectives. Successful implementation of public investments are bounded with both the availability of projects with good returns and the capacity of authorities to manage them.<sup>3</sup> In addition, fiscal solvency and sustainability constraints may prevent governments from incurring large deficits and accumulating excessive public debt. Last, but not least, policy makers are also concerned with the distribution of wealth across generations. Thus, facing different implementation constraints, resource horizons, and initial conditions, the desired scale and pace of such investments may be determined differently across different economies.

In this paper, we compare alternative public investment paths in terms of their impact on growth in the non-oil sector and fiscal outcomes. Central to the conduct of fiscal policy is a resource fund that receives inflows from revenue from the taxation of oil profits and interest payments from the accumulation of assets. Public investment is part of the

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<sup>1</sup>See Abdelal *et al.* (2008) for an analysis of this shift in investment strategies in the context of the Gulf Cooperation Council (GCC).

<sup>2</sup>See <http://www.bloomberg.com/news/articles/2016-04-01/saudi-arabia-plans-2-trillion-megafund-to-dwarf-all-its-rivals>

<sup>3</sup>See Albino-War *et al.* (2014) for an analysis on the importance of public investment management in oil-rich countries.

outflow from the fund. Then our aim is to answer the following questions for a sizeable oil discovery in a small economy that adds to the fund:

- What are the desired scale and pace of public investments over time?
- How should public investments be allocated over physical and human capital?

In order to answer these questions, we develop a multi-sector, small open economy Dynamic Stochastic General Equilibrium (DSGE) model that is based on Melina *et al.* (2016). We add to the latter, on the one hand, the accumulation of human capital, built via public expenditures in education and health expenditures; and, on the other, a richer array of fiscal options as far as the usage of natural resource revenues is concerned. These include Permanent Income (PIH) and Bird-in-Hand (BIH) based rules.

The model characterizes multiple types of public sector debt, multiple tax and spending variables, and a resource fund. The country produces a composite of traded goods and a nontraded goods using capital, labor, and its productivity is affected by government-supplied infrastructure, health and education. It is also endowed with natural resources, the production and prices of which are assumed to be exogenous. Since the time horizon is 20+ years, the model abstracts from money and all nominal rigidities.<sup>4</sup>

The model has a number of important features specific to LIDCs. These are financially constrained households who do not have access to capital and financial markets and consume all of their disposable income each period; remittances received by households; a productivity effect of health and education; investment adjustment costs; international grants received by the government; public investment inefficiencies and absorptive capacity constraints, and finally a resource fund. It includes also standard distortionary taxes and investment adjustment costs.

We calibrate our model by using the available data from Kenya, which discovered an estimated 600 million barrels of oil in 2012 and is expected to start commercial production in the early 2020s. Although the proven reserves are relatively small in comparison to other oil producers, the revenues generated from them, which could reach 16 percent of GDP annually at peak, are likely to be significant for the Government of Kenya.

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<sup>4</sup>The nominal side and New Keynesian features may be added if the model is used to study the short-run policy effects of fiscal management to resource revenue flows.

Overall, our analysis suggests that the permanent income hypothesis approach best suits the characteristics of Kenya’s economy. The most relevant criteria for Kenya in deciding on the optimal approach are the impacts on the non-resource economy, efficiency of spending, and sustainability of fiscal outcomes. The simulations show that spending resource revenues as they become available is wasteful and incapable of delivering a better result than other approaches in promoting non-resource growth and sustainability in fiscal balances. Moreover, this approach is most likely to trigger Dutch disease symptoms in the medium term. In contrast, saving all the revenues (as in the BIH approach) is too stringent. Although this approach helps to build large quantities of fiscal buffers, it falls short of boosting the non-resource economy with much needed investments in infrastructure, education, and health. In comparison, the PIH and MF approaches facilitate non-resource growth; however, the PIH approach performs much better in fiscal outcomes.

Similarly, a balanced investment composition is expected to deliver the best long-term development results in Kenya. The simulations in this section show that a BC investment approach brings the highest boost to non-resource GDP and leads to favorable fiscal outcomes. This outcome is derived from the economic principle of diminishing returns to investment, which is especially true when there are implementation constraints. Therefore, even if investments in physical capital are scaled up rapidly, in the absence of accompanying improvements in public investment efficiency and matching buildup of private and human capital, resources are likely to be wasted.

This paper contributes to a growing literature on managing resource revenues for developing countries. This has evolved from advising to save most of a resource windfall in a sovereign wealth fund (e.g., Davis *et al.*, 2001; Barnett and Ossowski, 2003; Bems and de Carvalho Filho, 2011), to recommending to invest the windfall to build productive capital (e.g., van der Ploeg, 2010; Venables, 2010; van der Ploeg and Venables, 2011; Araujo *et al.*, 2013). DIGNAR encompasses many of the issues at stake in resource abundant countries by combining the models developed in Buffie *et al.* (2012) and Berg *et al.* (2013) into a suitable framework for assessing debt sustainability and growth benefits of public investment surges. DIGNAR, however, does not allow to make the distinction between physical and human capital, which we make in this paper. Agénor and Nganou (2013) consider different forms of physical and human capital in an overlapping generations frame-

work for Uganda; however, their analysis is concerned with steady state results and does not investigate dynamic aspects of the problem.

The paper continues as follows. The next section introduces the building blocks of a small open economy that lies at the foundation of the model. The third section adds the characteristics of natural resource finds in a low income country. The fourth section describes the fiscal approaches we use in simulations. The fifth section summarizes the simulation results for Kenya, and the final section provides concluding comments.

## 2 The core small open economy model

For the sake of exposition, in this section we present a simplified core small open economy model featuring public investment in physical and human capital, abstracting from distortionary taxes and a number of frictions and additional features that instead we present in Section 3.

### 2.1 Households

Households consume a consumption basket  $c_t$ , which is defined as a constant-elasticity-of-substitution (CES) function of traded goods,  $c_{T,t}$ , and nontraded goods,  $c_{N,t}$ . Thus, the consumption basket is

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

where  $1-\varphi$  indicates the degree of trade openness.

The consumption basket is the numeraire of the economy;  $p_{N,t}$  represents the relative price of non-traded goods, and  $p_{T,t}$  is the relative price of traded goods to the consumption basket. Assuming that the law of one price holds for traded goods implies that  $p_{T,t}$  also corresponds to the real exchange rate, defined as the price of one unit of foreign consumption basket in units of the domestic basket. The unit price of the consumption basket therefore is

$$1 = \left[ \varphi p_N^{1-\chi} + (1-\varphi) p_{T,t}^{1-\chi} \right]^{\frac{1}{1-\chi}}. \quad (2)$$

The representative household maximizes its inter-temporal utility at time  $t$

$$\mathbb{E}_t \sum_{s=0}^{\infty} \beta^{t+s} U(c_{t+s}, l_{t+s}^s), \quad (3)$$

with respect to  $\{c_{t+s}\}, \{l_{t+s}^s\}$ , subject to the following budget constraint,

$$c_t + b_t + p_{T,t} b_t^* = w_t l_t^s + R_{t-1} b_{t-1} + p_{T,t} R_{t-1}^* b_{t-1}^* - \Theta(b_t, b_t^*) + \text{exogenous income}, \quad (4)$$

where  $\mathbb{E}_t$  is the rational expectation operator at time  $t$ ,  $\beta$  is the subjective discount factor and  $l_t^s$  is labor supply. Households have access to government bonds  $b_t$  that pay a gross real interest rate  $R_t$ , hold net foreign assets  $b_t^*$  that pay a gross real interest rate  $R_t^*$ , and are remunerated for their labor services at the wage rate  $w_t$ . To prevent  $b_t^*$  from being a unit-root process we introduce  $\Theta_t \equiv \frac{\eta}{2} (b_t^* - b^*)^2$ , which are portfolio adjustment costs associated to foreign liabilities, where  $\eta$  controls the degree of capital account openness and  $b^*$  is the initial steady-state value of private foreign debt.<sup>5</sup> Households also receive exogenous income in the form of profits from firms in the traded and non-traded goods sectors and a lump-sum transfer from the government (which can be negative). There are no distortionary taxes at this stage of the modeling.

First order conditions for households are:

$$c_{N,t} = \varphi \frac{c_t}{(p_{N,t})^\chi}, \quad (5)$$

$$c_{T,t} = (1 - \varphi) \frac{c_t}{(p_{T,t})^\chi}, \quad (6)$$

$$u_{c,t} = \beta R_t \mathbb{E}_t u_{c,t+1} = \frac{\beta R_t^*}{p_{T,t} - \eta(b_t^* - b^*)} \mathbb{E}_t s_{t+1}, \quad (7)$$

$$w_t = -\frac{u_{l,t}}{u_{c,t}}. \quad (8)$$

## 2.2 Firms

The economy has three production sectors: (i) a non-traded good sector indexed by  $N$ , producing output  $y_{N,t}$ ; (ii) a (non-resource) traded good sector indexed by  $T$ , producing output  $y_{T,t}$ ; and (iii) a natural resource sector indexed by  $O$ , producing output  $y_{O,t}$ . Since

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<sup>5</sup>These adjustment costs also ensure stationarity in this small open economy model, as discussed in Schmitt-Grohé and Uribe (2003).



resource-rich developing countries tend to export most of the resource output, for simplicity we assume that this is exported in its entirety. Total real GDP  $y_t$  in the economy is

$$y_t = p_{N,t}y_{N,t} + p_{T,t}y_{T,t} + p_{O,t}y_{O,t}. \quad (9)$$

### 2.2.1 Non-traded and traded goods sectors

In both sectors  $N$  and  $T$ , a representative firm produce output  $y_{N,t}$  and  $y_{T,t}$  with the following Cobb-Douglas technology,

$$y_{j,t} = z_j (A_{j,t}l_{j,t})^{\alpha_j} (k_{j,t-1})^{1-\alpha_j} (k_{G,t-1})^{\alpha_G}, \quad j = N, T \quad (10)$$

where  $z_j$  is a total factor productivity parameter,  $A_{j,t}$  is labor productivity,  $l_{j,t}$  is the labor input,  $k_{j,t}$  is end-of-period private capital,  $k_{G,t}$  is end-of-period public capital,  $\alpha_j$  is the labor share of income, and  $\alpha_G$  is the output elasticity to public capital.

Labor productivity,  $A_{j,t}$ , is in turn given by

$$A_{j,t} = z_{j,a} e_t^{\beta_{j,E}} h_t^{\beta_{j,H}}, \quad (11)$$

where  $z_{j,a}$  is a scaling parameter,  $e_t$  represents the average education of the labor force,  $h_t$  represents the average health status of the labor force, while  $\beta_{j,E}$  and  $\beta_{j,H}$  are the elasticities of labor productivity to education and health, respectively.

Both education and health, which are inputs to all sectors, are provided by the government, and the relationship between government expenditures and education and health outcomes are given by

$$e_t = (1 - \delta_E) e_{t-1} + (\gamma^E g_{t-j_E}^E)^{\psi_E}, \quad (12)$$

and

$$h_t = (1 - \delta_H) h_{t-1} + (\gamma^H g_{t-j_H}^H)^{\psi_H}, \quad (13)$$

where  $g_t^E$  and  $g_t^H$  are public education and health expenditures,  $\delta_E$  and  $\delta_H$  are the respective depreciation rates,  $\gamma^E \in [0, 1]$  and  $\gamma^H \in [0, 1]$  are the respective efficiencies, and  $\psi^E \in [0, 1]$  and  $\psi^H \in [0, 1]$  are concavity parameters capturing absorptive capacity constraints. Time-to-build lags are accounted for when setting  $j_E > 1$  and  $j_H > 1$ .

Private capital evolves as

$$k_{j,t} = (1 - \delta_j) k_{j,t-1} + i_{j,t}, \quad j = N, T, \quad (14)$$

where  $i_{j,t}$  represents investment expenditure,  $\delta_j$  is private capital depreciation in sector  $j$ , and there are no investment adjustment costs. Aggregate private investment is then given by

$$i_t = \left[ \varphi^{\frac{1}{\chi}} (i_{N,t})^{\frac{\chi-1}{\chi}} + (1 - \varphi)^{\frac{1}{\chi}} (i_{T,t})^{\frac{\chi-1}{\chi}} \right]^{\frac{\chi}{\chi-1}}. \quad (15)$$

The representative firm maximizes its discounted lifetime profits weighted by the marginal utility of consumption of households  $\lambda_t$ . These profits are given by

$$\Omega_{j,t} = \mathbb{E}_t \sum_{s=0}^{\infty} \beta^{t+s} \lambda_{t+s} [p_{j,t+s} y_{j,t+s} - w_{j,t+s} l_{j,t+s} - i_{j,t}], \quad j = N, T. \quad (16)$$

First order conditions are:

$$w_t = \frac{\alpha_j p_{j,t} y_{j,t}}{l_{j,t}^d}; j = N, T, \quad (17)$$

$$\mathbb{E}_t R_{k_j,t+1} = R_t; j = N, T, \quad (18)$$

$$\frac{(1 - \alpha_j) p_{j,t} y_{j,t}}{k_{j,t}} = R_{k_j,t} - 1 + \delta_j; j = N, T, \quad (19)$$

and as for consumption goods,

$$i_{N,t} = \varphi \frac{i_t}{(p_{N,t})^\chi}, \quad (20)$$

$$i_{T,t} = (1 - \varphi) \frac{i_t}{(p_{T,t})^\chi}. \quad (21)$$

### 2.2.2 Natural resource sector

Since often most natural resource production in resource-rich developing countries is capital intensive, and much of the investment in the resource sector is financed by foreign direct investment, natural resource production is simplified in the model as follows. The value of resource production (in terms of the foreign consumption basket),  $y_{O,t}$ , follows an exogenous path. Each period, the government receives a constant fraction  $\tau^O$  of gross

revenues, capturing royalties and other taxes,

$$t_{O,t} = \tau^O p_{T,t} y_{O,t}. \quad (22)$$

Zero profits are assumed in the natural resource sector.

### 2.3 Government

The core model abstracts from government consumption and hence government purchases,  $g_t$  are all for public investment in physical capital,  $g_t^I$ , education  $g_t^E$  and health  $g_t^H$ . Like private consumption, government investment is also a CES aggregate of domestic traded goods,  $g_{T,t}$  and domestic non-traded goods,  $g_{N,t}$ . Thus,

$$g_t = \left[ \varphi_I^{\frac{1}{\chi}} (g_{N,t})^{\frac{\chi-1}{\chi}} + (1 - \varphi_I)^{\frac{1}{\chi}} (g_{T,t})^{\frac{\chi-1}{\chi}} \right]^{\frac{\chi}{\chi-1}}. \quad (23)$$

As for consumption and investment goods we then have

$$g_{N,t} = \varphi_I \frac{g_t}{(p_{N,t})^\chi} \quad (24)$$

$$g_{T,t} = (1 - \varphi_I) \frac{g_t}{(p_{T,t})^\chi} \quad (25)$$

Public capital accumulation evolves as equation as

$$k_{G,t} = (1 - \delta_G) k_{G,t-1} + g_t^I, \quad (26)$$

where  $\delta_G$  is the depreciation rate of public capital.

The government flow budget constraint is given by

$$b_t = R_{t-1} b_{t-1} + p_t^G g_t - t_{O,t} \quad (27)$$

where

$$g_t = g_t^I + g_t^E + g_t^H \quad (28)$$

and  $p_t^G$  is the government spending price index,

$$p_t^G = \left[ \varphi p_{N,t}^{1-\chi} + (1-\varphi) p_{T,t}^{1-\chi} \right]^{\frac{1}{1-\chi}}. \quad (29)$$

The levels of public education, health and physical capital expenditures are set as fractions of total government investment,

$$g_t^E = \phi_t^E g_t, \quad (30)$$

$$g_t^H = \phi_t^H g_t, \quad (31)$$

$$g_t^I = (1 - \phi_t^H - \phi_t^E) g_t, \quad (32)$$

with

$$\phi_t^E = \begin{cases} \phi_{init}^E & \text{for } t = 0, \\ \phi_{new}^E & \text{for } t > 0, \end{cases} \quad (33)$$

$$\phi_t^H = \begin{cases} \phi_{init}^H & \text{for } t = 0, \\ \phi_{new}^H & \text{for } t > 0, \end{cases} \quad (34)$$

where fractions  $\phi_{init}^E, \phi_{init}^H \in [0, 1]$  are the observed fractions at the initial steady state, and  $\phi_{new}^E, \phi_{new}^H \in [0, 1]$  are policy parameters that determine the allocation of the public investment scaling up among education, health and physical capital expenditures. The path for total investment  $g_t$  is set according to one of the fiscal regimes described in Section 4.

## 2.4 Identities and market clearing conditions

To close the model, the goods market clearing condition and the balance of payment condition are imposed. The market clearing condition for non-traded goods is

$$y_{N,t} = c_{N,t} + i_{N,t} + g_{N,t}, \quad (35)$$

The balance of payment condition corresponds to

$$\frac{ca_t}{p_{T,t}} = \Delta b_t^*, \quad (36)$$

where  $ca_t$  is the current account surplus,

$$ca_t = y_t - c_t - i_t - g_t + (R_{t-1}^* - 1) p_{T,t} b_{t-1}^*. \quad (37)$$

where  $tb_t = y_t - c_t - i_t - g_t$  is the trade balance.

The labor market equilibrium implies that

$$l_{N,t}^d + l_{T,t}^d = l_t^s. \quad (38)$$

To complete the solution for numerical computation we choose a standard household utility function

$$u(c_t, l_t) = \frac{1}{1-\sigma} c_t^{1-\sigma} - \frac{\kappa}{1+\psi} (l_t^s)^{1+\psi} \quad (39)$$

where  $\sigma$  is the inverse of the inter-temporal elasticity of substitution of consumption,  $\psi$  is the inverse of the inter-temporal elasticity of substitution of the labor supply and  $\kappa$  is the disutility weight of labor. Then

$$u_c = c_t^{-\sigma} \quad (40)$$

$$u_l = -\kappa (l_t^s)^\psi \quad (41)$$

### 3 Additional features

Following Melina *et al.* (2016) we enrich the core model by adding model features particularly relevant for LIDC. Three of these – distortionary taxes, credit-constrained consumers and investment adjustment costs – are now very common in DSGE models and we refer the reader to Melina *et al.* (2016) or similar papers for details. The remaining features are less standard, hence we report them in turn.

#### 3.1 Public investment efficiency and absorptive capacity constraints

Public investment features inefficiency and absorptive capacity constraints. Hulten (1996) and Pritchett (2000) argue that often high productivity of infrastructure can coexist with very low returns on public investment in developing countries, because of inefficiencies in investing. As a result, public investment *spending* does not necessarily increase the stock

of productive capital and, therefore, growth. Similarly, absorptive capacity constraints related to technical capacity and waste and leakage of resources in the investment process—which impact project selection, management, and implementation—can have long lasting negative effects on growth, as suggested by Esfahani and Ramirez (2003), among others.

To reflect these inefficiencies and constraints, we assume that effective investment  $\tilde{g}_t^I(\bar{\gamma}_t^{GI})$  is a function of the public investment growth rate ( $\bar{\gamma}_t^{GI}$ ) relative to its steady state value, and  $\bar{\gamma}_t^{GI} \equiv \frac{g_t^I}{g^I} - 1$ . Specifically,

$$\tilde{g}_t^I = \begin{cases} \bar{e}g_t^I, & \text{if } \bar{\gamma}_t^{GI} \leq \bar{\gamma}^{GI} \\ \bar{e}(1 + \bar{\gamma}^{GI})\bar{g}^I + \epsilon(\bar{\gamma}_t^{GI})[1 + \bar{\gamma}_t^{GI} - \bar{\gamma}^{GI}]\bar{g}^I, & \text{if } \bar{\gamma}_t^{GI} > \bar{\gamma}^{GI} \end{cases}, \quad (42)$$

where  $\bar{e} \in [0, 1]$  represents steady-state efficiency and  $\epsilon(\bar{\gamma}_t^{GI}) \in (0, 1]$  governs the efficiency of the portion of public investment exceeding a threshold  $\bar{\gamma}^{GI}$ , in percent deviation from the initial steady state. We assume that  $\epsilon(\bar{\gamma}_t^{GI})$  takes the following specification:

$$\epsilon(\bar{\gamma}_t^{GI}) = \exp[-\varsigma_\epsilon(\bar{\gamma}_t^{GI} - \bar{\gamma}^{GI})]\bar{e}. \quad (43)$$

In other words, if the growth rate of government investment expenditure from the initial steady state exceeds  $\bar{\gamma}^{GI}$ , then the efficiency of the additional investment decreases, reflecting the presence of absorptive capacity constraints. The severity of these constraints is governed by the parameter  $\varsigma_\epsilon \in [0, \infty)$ .

The law of motion of public capital is described as

$$k_{G,t} = (1 - \delta_{G,t})k_{G,t-1} + \tilde{g}_t^I, \quad (44)$$

where  $\delta_{G,t}$  is a time-varying depreciation rate of public capital in the spirit of Rioja (2003). Since insufficient maintenance can shorten the life of existing capital, we assume that the depreciation rate increases proportionally to the extent to which effective investment fails

to maintain existing capital.<sup>6</sup> Therefore

$$\delta_{G,t} = \begin{cases} \phi \delta_G \frac{\delta_G k_{G,t-1}}{\tilde{g}_t^I}, & \text{if } \tilde{g}_t^I < \delta_G k_{G,t-1} \\ \rho_\delta \delta_{G,t-1} + (1 - \rho_\delta) \delta_G, & \text{if } \tilde{g}_t^I \geq \delta_G k_{G,t-1} \end{cases}, \quad (45)$$

where  $\delta_G$  is the steady-state depreciation rate,  $\phi \geq 0$  determines the extent to which poor maintenance produces additional depreciation, and  $\rho_\delta \in [0, 1)$  controls its persistence.<sup>7</sup>

### 3.2 The resource fund and the fiscal gap

Central to fiscal policy is the *resource fund* which we model along the lines of Berg *et al.* (2013). A resource windfall is defined as resource revenues that are above their initial steady-state level, i.e.,  $t_t^O - t^O$ . Let  $f_t^*$  be the foreign financial asset value in a resource fund and  $f^*$  be its initial steady state. Each period, the resource fund earns interest income  $p_{T,t} (R^{rf} - 1) f_{t-1}^*$ , with a constant gross foreign real interest rate  $R^{rf}$ . The resource fund evolves by the process

$$f_t^* - f^* = \max \left\{ f_{floor} - f^*, (f_{t-1}^* - f^*) + \frac{f_{in,t}}{p_{T,t}} - \frac{f_{out,t}}{p_{T,t}} \right\}, \quad (46)$$

where  $f_{in,t}$  represents the total fiscal inflow,  $f_{out,t}$  represents the total fiscal outflow, and  $f_{floor} \geq 0$  is a lower bound for the fund that the government chooses to maintain. If no minimum savings are required in a resource fund, the lower bound can be set at zero. At each point in time, if the fiscal inflow exceeds the fiscal outflow, the value of the resource fund increases. Instead, if the resource fund is above  $f_{floor}$ , any fiscal outflow that exceeds the fiscal inflow is absorbed by a withdrawal from the fund. Whenever the floor of a resource fund binds, the fiscal gap is covered via borrowing and/or increases in taxes (on consumption and factor incomes) or cuts in government non-capital expenditures (government consumption and transfers).

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<sup>6</sup>Adam and Bevan (2014) find that accounting for the operations and maintenance expenditures of installed capital is crucial for assessing the growth effects and debt sustainability of a public investment scaling-up.

<sup>7</sup>Rioja (2003) separates investment expenditures between those for new projects and those for maintenance, and the depreciation rate is correlated positively with private capital to capture the intensity of public capital usage and negatively with maintenance expenditures.

The fiscal inflow and outflow are given by

$$f_{in,t} = t_{O,t} + p_{T,t} (R^{rf} - 1) f_{t-1}^* + \text{tax revenues and international grants} \quad (47)$$

$$f_{out,t} = p_t^G g_t + \text{interest rate payments on borrowing} \quad (48)$$

where resource revenues  $t_{O,t} = \tau^O p_{T,t} y_{O,t}$ , where  $y_{O,t}$  and  $\tau^O$  are oil production and the royalty tax rate follow exogenous paths discussed below. Then the the fiscal gap is given by

$$gap_t = f_{out,t} - f_{in,t} + p_{T,t} (f_t^* - f_{t-1}^*), \quad (49)$$

Covering the fiscal gap then requires a combination of borrowing and adjustments to government spending and tax rates. Apart from the two components of government investment,  $g_t^I$  and  $g_t^E$ , considered later, the latter respond to the fiscal gap so that government debt is placed on a stable sustainable path.<sup>8</sup>

## 4 Four fiscal regimes

One of the purposes of the model is to analyze the effects of investing a resource windfall. The simulations presented in this paper focus on four investing approaches: spend-as-you-go (SAYG), bird-in-hand spending (BIH); moderate front-loading (MF) and permanent income hypothesis (PIH). These approaches are formulated as follows.

- **Spend-as-you-go (SAYG).** With spend-as-you-go, the resource fund stays at its initial level ( $f_t^* = f^*, \forall t$ ), and the entire windfall is spent in public investment projects:

$$p_t^G g_t - p^G g = \left( \frac{t_t^O}{p_{T,t}} - \frac{t^O}{s} \right). \quad (50)$$

- **Bird-in-hand spending (BIH).** With bird-in-hand, only the interest earned is spent:

$$p_t^G g_t - p^G g = p_{T,t} (R^{rf} - 1) f_{t-1}^* \quad (51)$$

- **Moderate frontloading (MF).** With moderate frontloading, investment is delinked

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<sup>8</sup>See the Appendix and Melina *et al.* (2016) for full details of the fiscal rules. In addition to these, to guarantee that the resource fund is not an explosive process, we assume that in the very long run, a small autoregressive coefficient  $\rho_f \in (0, 1)$  is attached to  $(f_{t-1}^* - f^*)$ .



from the resource fund. Then a scaling-up path of public investment is specified as a second-order delay function,

$$\frac{g_t}{g} = 1 + [1 + \exp(-k_1 t) - 2 \exp(-k_2 t)] g_{nss}, \quad (52)$$

where  $g_{nss}$  is the scaling-up investment target expressed as percentage deviation from the initial steady state,  $k_1 > 0$  represents the speed of adjustment of public investment to the new level, and  $k_2 \geq k_1$  represents the degree of investment frontloading.<sup>9</sup> In particular, if  $k_1 = k_2 = 0$ , public investment stays at its original steady-state level, i.e.,  $g_t = g \forall t$ .

- **Permanent income hypothesis (PIH).** This approach is arrived at by letting  $k_1, k_2 \rightarrow \infty$  and setting  $g_{nss}$  according to the PIH annuity as shown in Section 5. Then public investment jumps to the new steady-state level immediately.

## 5 Policy scenarios: application to Kenya

A series of commercial oil explorations in Northern Kenya have recently boosted prospects for Kenya's upstream oil industry. Discovered reserves estimated at 600 million barrels were announced in February 2014, and follow up explorations and appraisals have further de-risked the discovered resources. In addition, several companies have acquired blocks and are drilling (or planning to drill) both onshore and offshore. It will take several years before Kenya's oil and gas reserves have been assessed and the current slump in oil prices does not accelerate this process; nevertheless, the authorities are already considering the policy and development implications of this discovery.

In global terms, Kenya's discovered resources are relatively small. Kenya's 600 million barrel stock puts Kenya at 47th position worldwide in terms of oil reserves, just ahead of Uzbekistan. This quantity constitutes a small fraction of the reserves in resource rich African countries like Libya, Nigeria, Angola and Algeria, both in terms of absolute and per capita amounts. For comparison, Saudi Arabia produced about 11.5 million barrels

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<sup>9</sup>Differentiating (52) it can be shown that for  $k_2 > k_1$ ,  $g_t$  reaches a maximum at time  $t^{max} = \frac{1}{k_2 - k_1} \log(\frac{2k_2}{k_1})$  and that  $t^{max}$  is a decreasing function of  $\frac{k_2}{k_1}$ . Thus as  $k_2$  increases the investment path becomes more front-loaded. In principle  $k_1$  and  $k_2$  can be chosen to be optimal in relation to a policymaker's objectives. This aspect is left for future research.

of oil per day in 2012. With this speed of production, Kenya’s reserves would be depleted only in 52 days. In practice, however, the production in Kenya will be spread over a broader time frame, which reflects the time required to develop the fields and optimize the costs of production. Hence, based on the current exploration results, oil production will not be substantial over decade’s period and is unlikely to provide a global market niche for Kenya to specialize.

## 5.1 Fiscal revenue projections

Despite being small in global standards, oil and gas production is expected to have a non-negligible impact, especially on fiscal revenues. Kenya’s possible recoverable reserves could reach about 1.4 billion barrels of oil and 1.7 billion barrels oil equivalent of natural gas (PWC 2015). The most recent estimates show that oil production will start in 2022, and reach a plateau of about 77 million barrels a year soon after that (figure 5.2). Starting in 2032, production will decrease gradually, reflecting the maturing of existing fields. In comparison, the production of natural gas is estimated to start in 2025 and peak at 95 million barrels of oil equivalent per year in 2033. Calculating the fiscal revenues associated with these production profiles requires a detailed approach with information on cost profiles and the production agreements between the Government of Kenya and the producing companies. In the absence of such information, rough estimates, using World Bank oil price projections and general industry rules of thumb, show that Kenya’s fiscal revenues from oil production are projected to peak at about US\$8.9 billion in 2033. This is roughly equivalent to 16 percent of Kenya’s 2013 gross domestic product (GDP).

In light of these fiscal revenue projections, we next investigate the implications of alternative fiscal rule scenarios characterized in the previous section.

## 5.2 Calibration

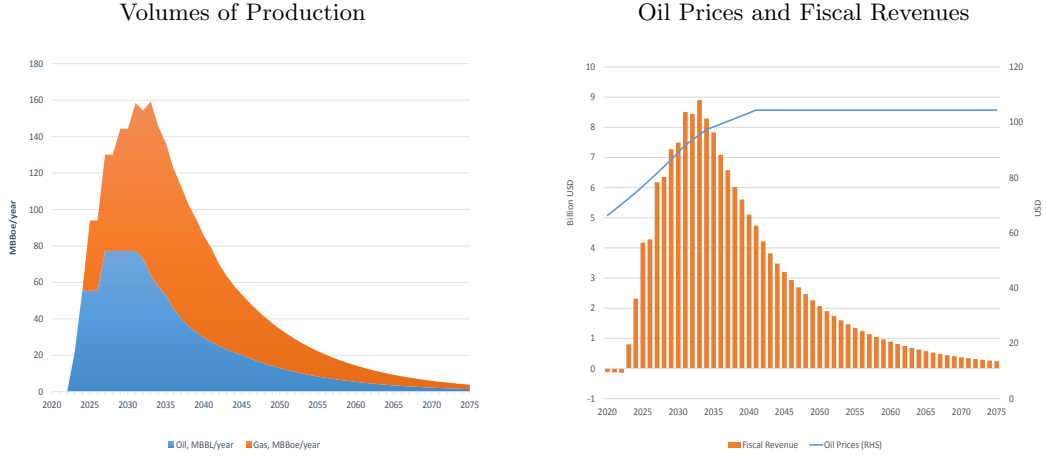
The full model, which is reported in the Appendix, is calibrated to Kenya at an annual frequency. Table 1 summarizes the baseline calibration, which is explained as follows.<sup>10</sup>

- *National accounting.* To reflect Kenya’s recent experience, the shares of exports and imports are set at 19 and 35 percent of GDP, respectively; government consumption

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<sup>10</sup>This section should be read in conjunction with the Appendix A.

Figure 1: Estimates for Oil Production and Fiscal Revenues (2015-2070)



and public investment are set at 16 and 8.6 percent of GDP, respectively, and private investment is set at 13.7 percent of GDP. We choose the shares of traded goods to be 60 percent in private consumption and 40 percent in government purchases, as government consumption typically have a larger component of nontraded goods than private consumption. The share of natural resources is 40 percent of GDP at the initial steady state.

- *Assets, debt and grants.* Government savings are 0 percent of GDP ( $RF_{share} = 0$ ) at the initial steady state. For government domestic debt, concessional debt, grants, as well as private foreign debt and government external commercial debt we rely on World Bank data. This implies  $b_{share} = 0.268$ ,  $d_{share} = 0.114$ ,  $gr_{share} = 0.01$ ,  $b_{share}^* = 0$  and  $d_{c,share} = 0.063$ .
- *Interest rates.* We set the subjective discount rate  $\rho$  such that the real annual interest rate on domestic debt ( $R - 1$ ) is 2.3 percent. Consistent with stylized facts, domestic debt is assumed to be more costly than external commercial debt. We fix the real annual risk-free interest rate ( $R^f - 1$ ) at 1.13 percent. The premium parameter  $v_{dc}$  is chosen such that the real interest rate on external commercial debt ( $R_{dc} - 1$ ) is 7 percent, and the real interest rate paid on concessional loans ( $R_d - 1$ ) is 1 percent. We assume no additional risk premium in the baseline calibration, implying  $\eta_{dc} = 0$ . The parameter  $u$  is chosen to have  $R = R^*$  in the steady state. Based on the average

Parameter	Value	Definition	Parameter	Value	Definition
$exp_{share}$	0.19	Exports to GDP	$\omega$	0.40	Measure of optimizers in the economy
$imp_{share}$	0.35	Imports to GDP	$\chi$	0.44	Substitution elasticity b/w traded/nontraded goods
$g_{share}^C$	0.16	Government consumption to GDP	$\eta$	1	Elasticity of portfolio adjustment costs
$g_{share}^I$	0.086	Government investment to GDP	$\tau^O$	-	Royalty tax rate on natural resources
$i_{share}$	0.137	Private investment to GDP	$f$	0.50	User fees of public infrastructure
$y_{O,share}$	0.40	Natural resources to GDP	$\tau^L$	0.05	Labor income tax rate
$g_{T,share}$	0.40	Share of tradables in government purchase	$\tau^C$	0.10	Consumption tax rate
$c_{T,share}$	0.60	Share of tradables in private consumption	$\tau^K$	0.20	Tax rate on the return on capital
$RF_{share}$	0	Stabilization fund to GDP	$f_{floor}$	0	Lower bound for the stabilization fund
$b_{share}$	0.268	Government domestic debt to GDP	$\varkappa$	1	Adjustment share by external commercial debt
$b_{share}^*$	0	Private foreign debt to GDP	$\lambda_1$	1	Adjustment share by consumption tax
$d_{share}$	0.114	Concessional debt to GDP	$\zeta_1$	0.5	Adjustment speed of consumption tax to target
$d_{c,share}$	0.063	Government external commercial debt/GDP	$\zeta_1$	0.001	Adjustment speed of consumption tax to target
$gr_{share}$	0.01	Grants to GDP	$\tau_{ceiling}^C$	$+\infty$	Ceiling on consumption tax
$(R - 1)$	0.023	Domestic net real interest rate	$\nu$	0.6	Home bias of government purchases
$(R^{RF} - 1)$	0.027	Foreign net real interest rate on savings	$\nu_g$	0.4	Home bias for additional spending
$(R_d - 1)$	0.01	Net real interest rate on concessional debt	$\alpha_G$	0.12	Output elasticity to public capital
$(R^f - 1)$	0.013	Net real risk-free rate	$\delta_G$	0.10	Depreciation rate of public capital
$(R_{dc,0} - 1)$	0.07	Net real interest rate on external commercial debt	$\bar{\epsilon}$	0.50	Steady-state efficiency of public investment
$\eta_{dc}$	0	Elasticity of sovereign risk	$k_1$	-	Speed of scaling up plan
$\alpha_N$	0.45	Labor income share in nontraded sector	$k_2$	-	Degree of frontloading
$\alpha_T$	0.60	Labor income share in traded sector	$\rho_\delta$	0.80	Persistence of depreciation rate of public capital
$\delta_N$	0.10	Depreciation rate of $k_{N,t}$	$\phi$	1	Severity of public capital depreciation
$\delta_T$	0.10	Depreciation rate of $k_{T,t}$	$\varsigma_\epsilon$	50	Severity of absorptive capacity constraints
$\rho_{yT}$	0.10	Learning by doing in traded sector	$\bar{\gamma}^{GI}$	0.60	Thresholds of absorptive capacity constraints
$\rho_{zT}$	0.10	Persistence in TFP in traded sector	$\psi_H, \psi_E$	0.60	Concavity parameters in human capital investment
$\kappa_N$	25	Investment adjustment cost, nontraded sector	$\gamma_H, \gamma_E$	0.19	Efficiency of human capital investment
$\kappa_T$	25	Investment adjustment cost, traded sector	$\dot{j}_E$	5	Time to build lag for education stock
$\psi$	10	Inverse of Frisch labor elasticity	$\dot{j}_H$	1	Time to build lag for health status
$\sigma$	2.94	Inverse of intertemporal elasticity of substitution	$\epsilon_E$	0.1	Output elasticity to education investment
$\rho$	1	Intratemporal substitution elasticity of labor	$\epsilon_H$	0.03	Output elasticity to health investment

Table 1: Baseline calibration

real return of the Norwegian Government Pension Fund from 1997 to 2011 (Gros and Mayer, 2012), the annual real return on international financial assets in the resource fund ( $R^{RF} - 1$ ) is set at 2.7 percent.

- *Private production.* Consistent with the evidence on Sub-Saharan Africa (SSA) surveyed in Buffie *et al.* (2012), the labor income shares in the nontraded and traded good sectors correspond to  $\alpha_N = 0.45$  and  $\alpha_T = 0.60$ . In both sectors private capital depreciates at an annual rate of 10 percent ( $\delta_N = \delta_T = 0.10$ ). Following Berg *et al.*

(2013), we assume a minor degree of learning-by-doing externality in the traded good sector ( $\rho_{Y_T} = \rho_{z_T} = 0.10$ ). Also as in Berg *et al.* (2010), investment adjustment costs are set to  $\kappa_N = \kappa_T = 25$ .

- *Households preferences.* The coefficient of risk aversion  $\sigma = 2.94$  implies an intertemporal elasticity of substitution of 0.34, which is the average LIC estimate according to Ogaki *et al.* (1996). We assume a low Frisch labor elasticity of 0.10 ( $\psi = 10$ ), similar to the estimate of wage elasticity of working in rural Malawi - see Goldberg (2013). The labor mobility parameter  $\rho$  is set to 1 as in Horvath (2000), and the elasticity of substitution between traded and nontraded goods is  $\chi = 0.44$ , following Stockman and Tesar (1995). To capture limited access to international capital markets, we set  $\eta = 1$  as in Buffie *et al.* (2012).
- *Measure of intertemporal optimizing households.* Since a large proportion of households in LICs are liquidity constrained, we pick  $\omega = 0.40$ , implying that 60 percent of households are rule-of-thumb. Depending on the degree of financial development of a country, the measure of intertemporal optimizing households can be lower than 40 percent in some SSA countries. Based on data collected in 2011, Demirguc-Kunt and Klapper (2012) report that on average only 24 percent of the adults in SSA countries have an account in a formal financial institution.
- *Mining.* The royalty tax rate  $\tau^O$  is made time-varying to match the projections of natural resource revenues for Kenya in Subsection 5.1.
- *Tax rates.* Consistently with data collected by the International Bureau of Fiscal Documentation in 2005-06, the steady-state taxes on consumption, labor and capital are chosen so that  $\tau^C = 0.10$ ,  $\tau^L = 0.15$ , and  $\tau^K = 0.20$ , respectively.
- *Fiscal rules.* In this application we use only the consumption tax rate as the instrument that stabilizes government debt. We impose a non-negativity constraint for the stabilization fund by setting  $f_{floor} = 0$ . In the baseline calibration, the fiscal instrument does not have a ceiling. This translates in setting  $\tau_{ceiling}^C = 100,000$ . The baseline calibration also implies that the whole fiscal adjustment takes place through changes in external commercial borrowing and consumption taxes. This is

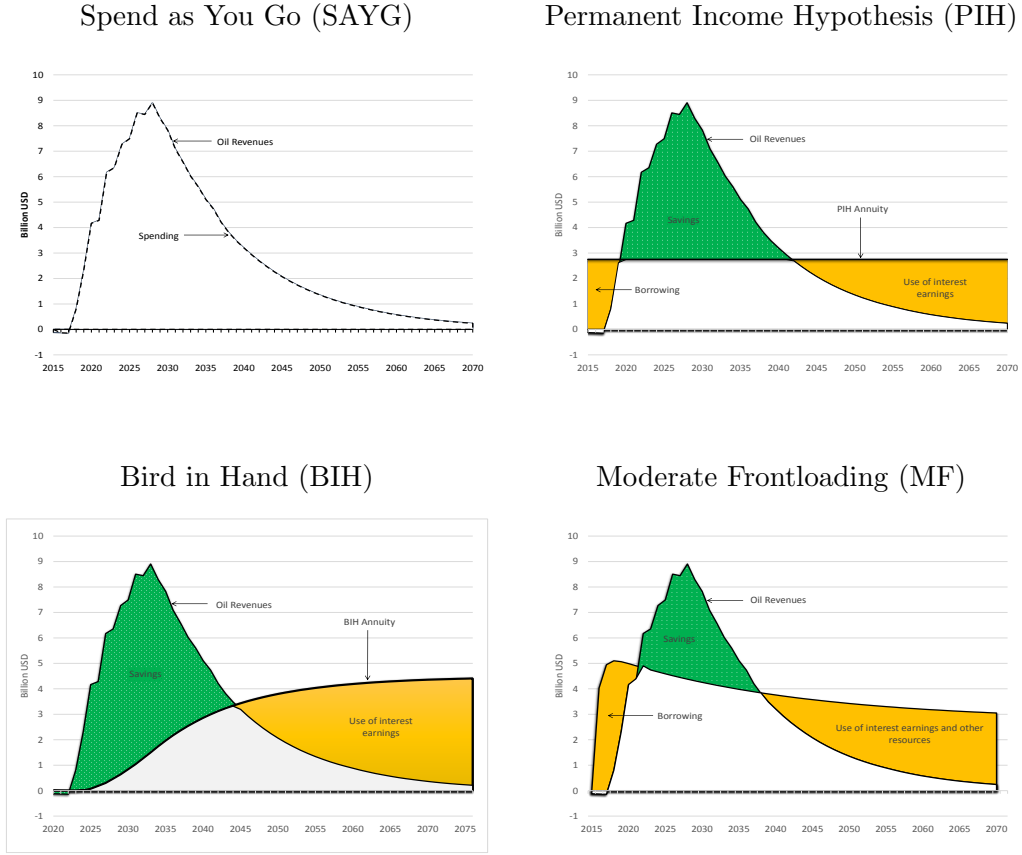
achieved by setting  $\kappa = \lambda_1 = 1$ . To smooth tax changes, we choose an intermediate adjustment of the consumption tax rate relative to its target ( $\zeta_1 = 0.5$ ) and a low responsiveness of the consumption tax rate to the debt-to-GDP ratio ( $\zeta_2 = 0.001$ ). The selection of values for these policy parameters should be guided by the policy scenario that the team wants to simulate as well as by what they consider feasible as a fiscal adjustment.

- *Public investment.* Public investment efficiency is set to 50 percent ( $\bar{\epsilon} = 0.5$ ), following estimates in Pritchett (2000) for SSA countries. The annual depreciation rate for public capital is 10 percent ( $\delta^G = 0.10$ ). The home bias for government purchases  $\nu$  and for investment spending above the initial steady-state level  $\nu^g$  are 0.6 and 0.4, respectively. The smaller degree of home bias in additional spending reflects that most of the investment goods are imported in LICs. The output elasticity to public capital  $\alpha^G$  is set at 0.12. The severity of public capital depreciation corresponds to  $\phi = 1$  and the change in the depreciation rate of public capital is assumed to be a persistent process by setting  $\rho_\delta = 0.8$ . In the baseline, absorptive capacity constraints start binding when public investment rises above 60 percent from its initial steady state ( $\bar{\gamma}^{GI} = 0.60$ ). The calibration of absorptive capacity constraints with  $\varsigma_\epsilon = 50$  implies that the average investment efficiency approximately halves to around 25 percent when public investment spikes to around 200 percent from its initial steady state.
- *Education and Health Parameters* Taking logs of the production functions in the non-traded and traded sectors we have

$$\log(y_j) = \alpha_j \psi_E \beta_{j,E} \log(g^E) + \alpha_j \psi_H \beta_{j,H} \log(g^H) + \text{other terms}; j = N, T \quad (53)$$

from which the elasticities of expenditure are given by  $\epsilon_i = \alpha_j \psi_i \beta_{j,i}$ ;  $j = N, T$ ;  $i = E, H$  from which given  $\psi_i$ ,  $\alpha_j$  and  $\epsilon_{j,i}$ , we can pin down  $\beta_{j,i}$ . The value chosen for the concavity parameter is  $\psi_i = 0.55$ , the efficiency parameters are  $\gamma_E = \gamma_H = 0.19$ , which imply an effective efficiency of 40 percent. In addition, we assume that health expenditures affect the stock of human capital after one year, while education expenditures after 5 years ( $j_H = 1$ ,  $j_E = 5$ ). Last a larger elasticity is assigned to

Figure 2: Alternative Fiscal Rules



education ( $\epsilon_E = 0.1$ ) relative to health ( $\epsilon_H = 0.03$ ).

### 5.3 Spending under alternative fiscal rules

At the beginning of the resource boom, the PIH leads to a deficit that needs to be financed externally. However, once the production of natural resource comes to an end, PIH and BIH imply an equivalent annuity that is equal to the returns on financial assets. Using the baseline revenue projections for Kenya, and assuming a 2.7 percent real interest earnings on savings, annuities under each fiscal rule is calculated and shown in the following figures.

The SAYG approach does not lead to any savings; therefore, transfers to the budget from the resource boom diminish over time, following the resource revenue depletion.

Under PIH, the government transfers about \$2.7 billion to the fiscal budget annually (figure 2, black line in panel b). In the short term, this is financed by borrowing from

abroad (the first yellow shaded area), as resource revenues are relatively low at this stage. In the medium term, the resource revenues pick up and reach a peak of about \$9 billion. The difference between revenues and transfers is saved in a sovereign wealth fund (green shaded area). Finally, as the revenues gradually die out, interest earnings on the welfare fund assets are used to supplement the transfers to the budget (second yellow shaded area).

Under BIH, transfers to the fiscal budget are scaled up over time as resource revenues are saved in the sovereign wealth fund and interest earnings on wealth fund assets increase (black curve line in panel c). Until the early 2040s, resource revenues exceed the transfers; therefore, reserves continue to build up. Later in the projection horizon, accumulation comes to a halt and the BIH annuity reaches a plateau.

Finally, the “big push” under the MF approach leads to investments that are financed by borrowings in the short term (first yellow-shaded area). In the medium term, resource revenues exceed spending; however, the difference is smaller than with PIH or BIH. Moreover, the spending converges to the PIH annuity in the long-term; however, spending remains above the PIH. Therefore, stabilization fund savings would be a lot smaller than the levels with PIH or BIH.

## 5.4 Implications of fiscal rules for growth and public finances

All approaches assume an increase in public investments; the difference between them lies in the timing and scale of the increases. Figure 3 shows the evolution of investments under each approach using the baseline oil price, output and exchange rate projections. The SAYG approach mimics the dynamics of oil revenues illustrated by the inverted-U shape in figure 1, panel b; it thus leads to an aggressive scaling-up of public investment expenditures toward the middle of the projection horizon. In about two decades, this approach reaches a maximum, more than doubling public investment expenditures compared with the initial level. In comparison, the MF and PIH approaches bring about a permanent and relatively moderate rise at the outset. The MF approach increases public investment expenditures to a maximum of 100 percent relative to the initial level before it gradually approaches about 50 percent; the steady increase implied by the PIH. The BIH approach gradually scales up public investments, reaching SAYG only in the mid-2040s when the expenditures



under the latter approach are reduced rapidly.

However, absorptive capacity constraints impose a “speed limit” on scaling up public investments in an efficient manner. The simulations show that higher spending does not automatically translate into a proportionate increase in public capital. In the short term, a rapid scaling-up under the MF approach leads to significant losses in average infrastructure efficiency. However, the loss is significantly larger under the SAYG approach. As a result, although the SAYG spends significantly more, the two approaches lead to similar levels of public capital accumulation (about 60 percent greater than the initial equilibrium) by the mid-2050s. This shows that the additional spending under the SAYG is wasted.

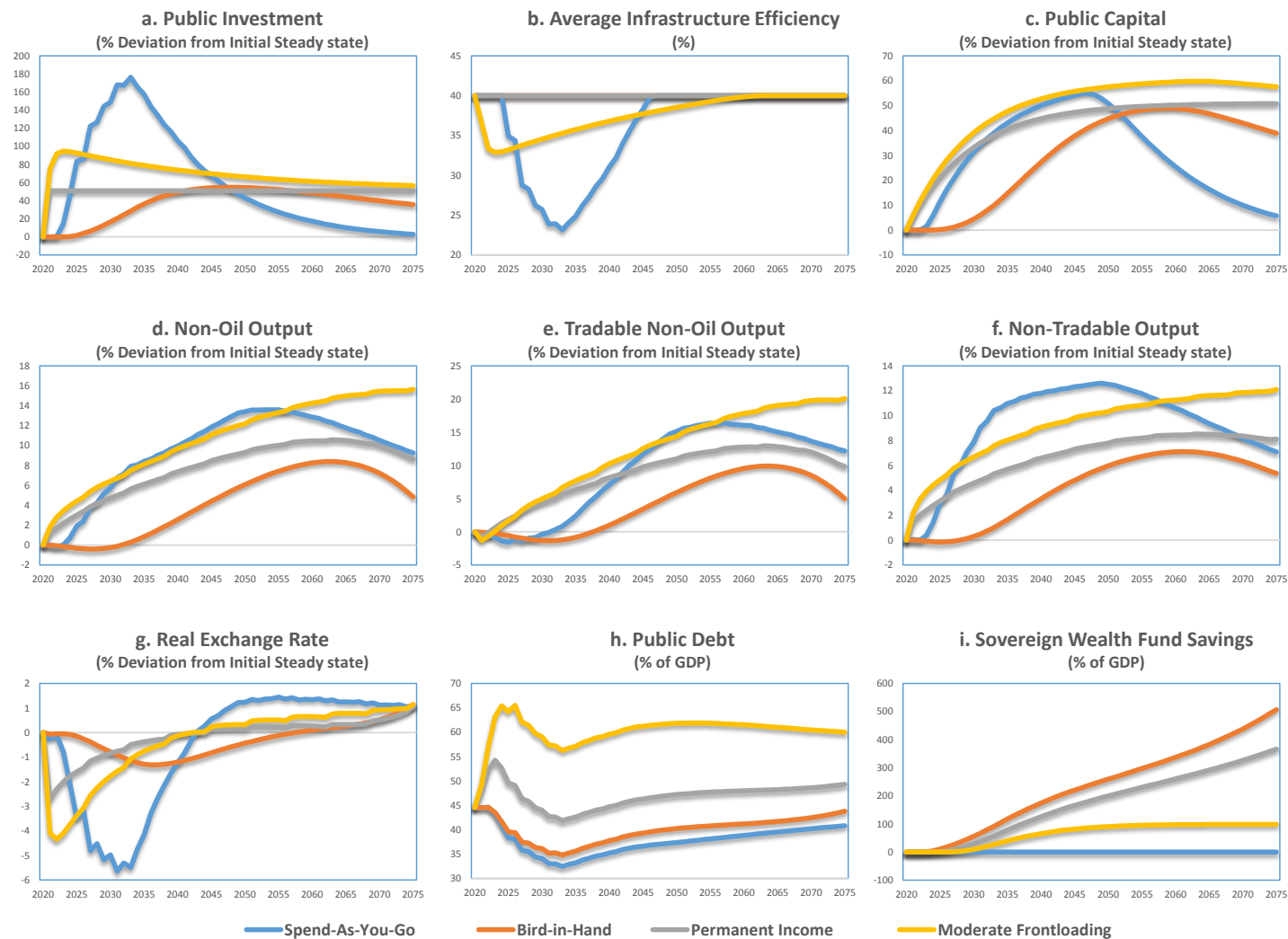
Non-resource GDP responds to higher public expenditure levels; yet, this impact is not sustainable under the SAYG approach. Although the speed limit reduces public capital accumulation under the SAYG approach, the large scaling-up of investments still has a significant medium-term impact on non-resource GDP. At its peak, non-resource GDP is about 13 percent greater than its initial equilibrium value. This is partially because higher expenditures not only increase the infrastructure investments, but also build up more physical and human capital, which do not suffer from absorptive capacity constraints. However, this impact is not sustainable, because the resource revenues are depleted toward the end of the projection horizon. In comparison, steady spending under the PIH and MF approaches brings the non-resource GDP close to or even higher than the SAYG value in the long term, with the MF exceeding it by more than 5 percentage points. The BIH approach, by contrast, keeps the non-oil GDP close to its initial levels for a long time before the interest earnings become large enough to have a significant impact on non-resource GDP, which occurs only around three decades after the revenue starts to flow.

The sector composition of the GDP shifts significantly under the different expenditure policies. All the approaches, apart from SAYG, lead to a gradual and relatively balanced expansion of non-resource GDP over the projection horizon. In contrast, the SAYG approach leads to more prominent Dutch disease-like symptoms. Under the MF and PIH approaches, the tradable and non-tradable sectors grow at a relatively stable rate. For the BIH approach, the growth rates in both sectors are relatively back-loaded, but they are balanced across sectors. In contrast, the SAYG approach leads to a rapid expansion of the non-tradable sector early in the projections (up to 12 percentage points higher than

the initial equilibrium), which is sustained for a prolonged period of time. The expansion of the tradable sector comes in the second half of the projection horizon, and is relatively short-lived. These differences in the sector compositions can be traced back to Dutch disease symptoms in the economy. The rapid escalation of expenditures under the SAYG approach leads to a significant and sustained appreciation of the domestic currency in the first half of the projection horizon. This leads to an erosion of competitiveness in the tradable sector. Currency appreciations under the PIH and MF approaches, however, are relatively short-lived and limited to the early years.

The PIH and BIH approaches lead to better and more sustainable fiscal outcomes. The simulations evaluate the fiscal implications by comparing asset and liability accumulations under each approach. The lowest debt-to-GDP ratio is generated by the SAYG approach, because there is no debt issuance for financing investments in this case. The debt-to-GDP ratio thus decreases from about 45 percent in the beginning of the projections to 42 percent by 2075. However, there is no accumulation of savings either. In contrast, the MF approach raises public debt the most because of the initial “big push.” The debt-to-GDP ratio increases from about 45 percent to close to 60 percent over the projection horizon. At the same time, the oil revenue savings reach about 90 percent of the current GDP. However, the true winners for fiscal sustainability are the more conservative approaches. Under the BIH approach, the debt-to-GDP ratio decreases by about 2 percentage points, and stabilization fund balances exceed four times the current GDP by 2075. Similarly, the savings under the PIH approach exceeds 3.5 times the GDP. A slightly smaller accumulation compared with the BIH approach reflects the borrowings to finance the initial escalation of public investments.

Figure 3: Real Economy and Public Finance Implications of Alternative Fiscal Rules



## 5.5 Taking investment composition into consideration

The fiscal rule exercise in the previous section analyzed the effects of changing intertemporal composition of public investments on the real economy and public finances. This has been done while holding the allocation of investments across alternative uses fixed at their initial levels. The simulations in this section do the opposite: they compare alternative compositions of public investments on the basis of their long-term implications while holding the intertemporal allocation of aggregate public investments fixed at a given path. In order to see the intuition for such an exercise, note that actual investment paths for education, health, and infrastructure are determined by two forces that are defined by policy decisions. The first one is the ‘scale effect’, which describes the changes in the level of total public investments. Public investment expenditure scenarios described in the previous section determine the magnitude of this effect. The second one is the ‘composition effect’, which describes the structure of spending. In order to analyze the latter effect, the scale of expenditures will be held fixed as given by the Permanent Income Hypothesis (PIH) approach. Then, three alternatives to the allocation of spending on infrastructure, education, and health will be compared on the basis of their long-term growth and fiscal implications:

- **Aggressive Infrastructure-based Composition (AIC):** This approach keeps the shares of all components in total public investments fixed at their current levels, which are already high. These shares are, approximately: 70 percent infrastructure investments, 24 percent education, and 6 percent health. Total public investments are set as implied by the PIH approach; thus, both the size and composition of the investments are kept constant throughout the projection horizon.
- **Aggressive Skill-based Composition (ASC):** The share of education in public investments is gradually increased from the initial level to about 40 percent at the expense of investments on infrastructure, whereas the share of health is kept constant.
- **Balanced Composition (BC):** The share of health in public investments is gradually increased from the initial level to about 11 percent at the expense of infrastructure, whereas the share of education is kept constant.

For all types of investments, the scale effect dominates the composition effects. In the long term, education and health investments are higher than their initial levels under all three scenarios. Figure 4 shows that by the end of the projection horizon, investments in education increase from about 2 percent of 2020 GDP to about 3 percent, and health investments increase from about 0.6 percent of 2020 GDP to about 0.8 percent, even when the AIC is chosen. The investments in each category never fall below the initial levels in these simulations, mainly because the additional investments generated by the PIH approach are large enough to compensate any potential losses if an unfavorable composition approach is chosen. This is particularly clear in the case of infrastructure investments: they increase from about 6 percent of GDP in 2020 to about 6.5 percent in the same period if ASC is chosen. Proportionately this increase is small because physical capital depreciates faster than education and health. Gross investments in this case are just large enough to offset the depreciation under the ASC.

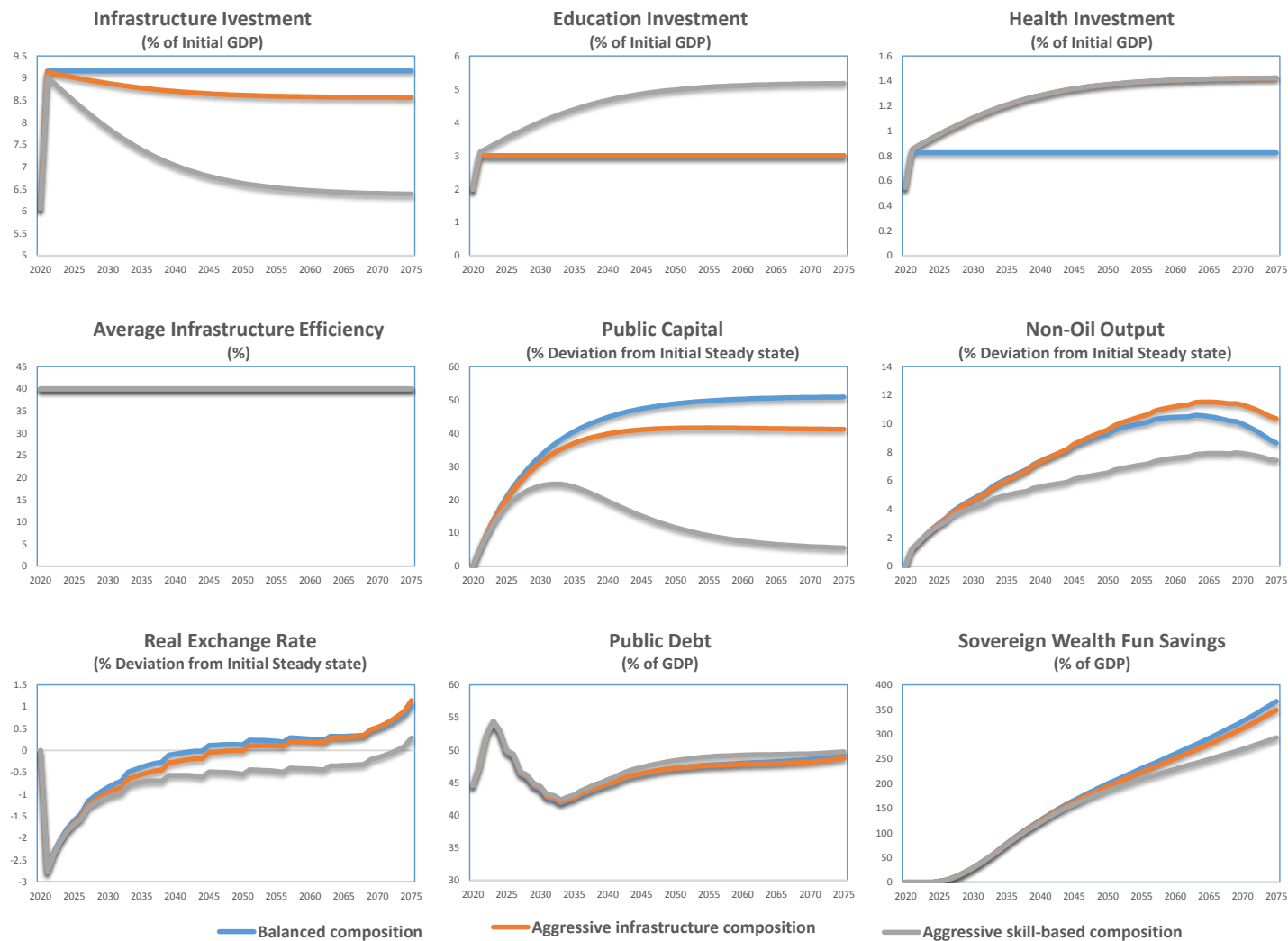
Simulations show that the limited scaling-up under the PIH approach saves the AIC from being punished heavily by the absorptive capacity constraint. A rapid scaling-up of public investments does not necessarily mean that public capital is scaled up quickly. Efficiency constraints in public investment projects bind most when infrastructure investments are scaled up rapidly as under the AIC approach. As a result, higher spending in this approach does not necessarily translate into faster capital accumulation if public investments are scaled up more rapidly than what the PIH approach suggests. However, when the PIH is chosen, this is not a problem. Thus, figure 4 shows that the gap between the public capital levels among the three approaches widens over time. By the end of the projection horizon, the gap between the AIC and BC is relatively small, whereas public capital shrinks toward its initial level under the ASC.

BC public investments translate into higher growth in the non-resource sector. Public capital stock under the BC approach is smaller than under the AIC in the second half of the projections. However, the human capital stock is greater. As a result, non-resource GDP under the BC approach grows more than it would under the AIC approach. This is mainly because infrastructure and human capital complement each other's productivity. With diminishing returns to each factor, this implies that increasing one factor at the expense of the other one would eventually decrease the total output. The BC approach leads to

a more balanced combination of physical and human capital, which is more conducive to long-term growth.

The three composition approaches bring about similar fiscal sustainability outcomes; however, the fiscal buffers are lower in the ASC case. Total public debt as a share of GDP remains similar in all the composition scenarios. In all cases, the public debt-to-GDP ratio climbs from about 45 percent in 2020 to about 55 percent in the medium term, and then stabilizes around 50 percent in the long term. Accumulation of savings in the stabilization fund exhibits significant differences. By the end of the projection horizon, the BC and AIC approaches lead to savings that are about 350 percent of GDP. The savings under the ASC approach are about 290 percent of GDP. As the GDP under the ASC approach is lower than the ones under other approaches, the gaps in savings-to-GDP ratios imply greater differences in savings in nominal terms.

Figure 4: Real Economy and Public Finance Implications of Alternative Fiscal Rules



## 6 Conclusions

This paper has developed a multi-sector, small open economy Dynamic Stochastic General Equilibrium (DSGE) model based on Melina *et al.* (2016), to include the accumulation of human capital, built via public expenditures in education and health expenditures. We have calibrated the model to Kenya and examined four possible fiscal rules for total public investment in infrastructure, education and health in the context of a sustainable resource fund. There are two dimensions to this exercise: the scaling effect which describes the level of total investment and the composition effect which defines the structure of investment between infrastructure, education and health. In terms of the impacts on the non-resource economy, efficiency of spending and sustainability of fiscal outcomes, we find that the PIH approach provides the best balance between effects on non-oil growth and fiscal sustainability in the case of Kenya. A balanced composition is the preferred structure of investment given the PIH allocation of total investment over time.

Our DSGE modeling approach to these issues offers an internally coherent framework for making conditional (i.e., *ceteris paribus*) forecasts of the effects of different fiscal policies. For the MF or PIH approaches these are defined in terms of parameters  $k_1$  and  $k_2$  that define the scaling effect, while the composition is driven by the share parameters at the beginning and end of the simulation period. Instead of restricting the choice to a limited and finite number of scenarios, future work could examine a welfare optimal choice of these parameters. Our exercise has been purely deterministic, ignoring uncertainty in crucial areas such as the world price of oil. A further line of research could study welfare-optimal state-contingent rules that indicate how policy would be adjusted in the face of unanticipated changes to the price of oil and other relevant exogenous macro-economic variables.

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## Appendix

### A The Full Model

Notation for the full model is as in Section 2 plus new variables:  $q_{T,t}, q_{N,t}$  for the price of capital in sectors T,N (arising from the introduction of adjustment costs of investment); consumption and labour distortionary taxes,  $\tau_t^C, \tau_t^L$ ; and external concessional commercial debt,  $d_t, d_{c,t}$  with loan gross rates  $R_{d,t}, R_{dc,t}$  respectively.

There are two sets of consumers: optimizing (OPT) and rule of thumb (ROT), the latter being credit-constrained and consuming disposable income in each period.

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

$$c_{N,t}^i = \varphi p_{N,t}^{-\chi} c_t^i; \quad c_{T,t}^i = (1-\varphi) s_t^{-\chi} c_t^i \quad \forall i = OPT, ROT \quad (\text{A.2})$$

$$1 = \left[ \varphi p_N^{1-\chi} + (1-\varphi) s_t^{1-\chi} \right]^{\frac{1}{1-\chi}} \quad (\text{A.3})$$

$$l_t^i = \left[ \delta^{-\frac{1}{\rho}} (l_{N,t}^i)^{\frac{1+\rho}{\rho}} + (1-\delta)^{-\frac{1}{\rho}} (l_{T,t}^i)^{\frac{1+\rho}{\rho}} \right]^{\frac{\rho}{1+\rho}}, \quad \text{for } i = OPT, ROT \quad (\text{A.4})$$

$$l_{N,t}^i = \delta \left( \frac{w_{N,t}}{w_t} \right)^{\rho} l_t^i, \quad l_{T,t}^i = (1-\delta) \left( \frac{w_{T,t}}{w_t} \right)^{\rho} l_t^i, \quad \text{for } i = OPT, ROT \quad (\text{A.5})$$

$$\lambda_t (1 + \tau_t^C) = (c_t^{OPT})^{-\sigma} \quad (\text{A.6})$$

$$\kappa^{OPT} (l_t^{OPT})^{\psi} = \lambda_t (1 - \tau_t^L) w_t \quad (\text{A.7})$$

$$\lambda_t = \beta E_t (\lambda_{t+1} R_t) \quad (\text{A.8})$$

$$\lambda_t = \beta E_t \left[ \frac{\lambda_{t+1} s_{t+1} R_t^*}{s_t - \eta (b_t^{OPT*} - b^{OPT*})} \right] \quad (\text{A.9})$$

$$R_t^* = R_{dc,t} + u \quad (\text{A.10})$$

$$(1 + \tau_t^C) c_t^{ROT} = (1 - \tau_t^L) w_t l_t^{ROT} + s_t r m_t^* + z_t - \mu k_{G,t-1} \quad (\text{A.11})$$

$$l_t^{ROT} = \left[ \frac{1}{\kappa^{ROT}} \frac{1 - \tau_t^L}{1 + \tau_t^C} (c_t^{ROT})^{-\sigma} w_t \right]^{\frac{1}{\psi}} \quad (\text{A.12})$$

$$c_t = \omega c_t^{OPT} + (1 - \omega) c_t^{ROT} \quad (\text{A.13})$$

$$l_t = \omega l_t^{OPT} + (1 - \omega) l_t^{ROT} \quad (\text{A.14})$$

$$b_t = \omega b_t^{OPT}; \quad b_t^* = \omega b_t^{OPT*} \quad (\text{A.15})$$

$$y_{N,t} = z_N (k_{N,t-1})^{1-\alpha_N} (A_{N,t} l_{N,t})^{\alpha_N} (k_{G,t-1})^{\alpha_G} \quad (\text{A.16})$$

$$k_{N,t} = (1 - \delta_N) k_{N,t-1} + \left[ 1 - \frac{\kappa_N}{2} \left( \frac{i_{N,t}}{i_{N,t-1}} - 1 \right)^2 \right] i_{N,t} \quad (\text{A.17})$$

$$w_{N,t} = \alpha_N p_{N,t} \frac{y_{N,t}}{l_{N,t}} \quad (\text{A.18})$$

$$q_{N,t} = E_t \left[ \beta \frac{\lambda_{t+1}}{\lambda_t} \left( (1 - \delta_N) q_{N,t+1} + (1 - \tau^K) (1 - \alpha_N) p_{N,t+1} \frac{y_{N,t+1}}{k_{N,t}} \right) \right] \quad (\text{A.19})$$

$$\begin{aligned} \frac{1}{q_{N,t}} &= \left[ 1 - \frac{\kappa_N}{2} \left( \frac{i_{N,t}}{i_{N,t-1}} - 1 \right)^2 - \kappa_N \left( \frac{i_{N,t}}{i_{N,t-1}} - 1 \right) \frac{i_{N,t}}{i_{N,t-1}} \right] \\ &+ E_t \left[ \beta \frac{\lambda_{t+1}}{\lambda_t} \kappa_N \frac{q_{N,t+1}}{q_{N,t}} \left( \frac{i_{N,t+1}}{i_{N,t}} - 1 \right) \left( \frac{i_{N,t+1}}{i_{N,t}} \right)^2 \right] \end{aligned} \quad (\text{A.20})$$

$$y_{T,t} = z_{T,t} (k_{T,t-1})^{1-\alpha_N} (A_{T,t} l_{T,t})^{\alpha_N} (k_{G,t-1})^{\alpha_G} \quad (\text{A.21})$$

$$\frac{z_{T,t}}{z_T} = \left( \frac{z_{T,t-1}}{z_T} \right)^{\rho_{zT}} \left( \frac{y_{T,t-1}}{y_T} \right)^{\rho_{yT}} \quad (\text{A.22})$$

$$k_{T,t} = (1 - \delta_T) k_{T,t-1} + \left[ 1 - \frac{\kappa_T}{2} \left( \frac{i_{T,t}}{i_{T,t-1}} - 1 \right)^2 \right] i_{T,t} \quad (\text{A.23})$$

$$w_{T,t} = \alpha s_t \frac{y_{T,t}}{l_{T,t}} \quad (\text{A.24})$$

$$q_{T,t} = E_t \left[ \beta \frac{\lambda_{t+1}}{\lambda_t} \left( (1 - \delta_T) q_{T,t+1} + (1 - \tau^K) (1 - \alpha_T) s_{t+1} \frac{y_{T,t+1}}{k_{T,t}} \right) \right] \quad (\text{A.25})$$

$$\begin{aligned} \frac{1}{q_{T,t}} = & \left[ 1 - \frac{\kappa_T}{2} \left( \frac{i_{T,t}}{i_{T,t-1}} - 1 \right)^2 - \kappa_T \left( \frac{i_{T,t}}{i_{T,t-1}} - 1 \right) \frac{i_{T,t}}{i_{T,t-1}} \right] \\ & + E_t \left[ \beta \frac{\lambda_{t+1}}{\lambda_t} \kappa_T \frac{q_{T,t+1}}{q_{T,t}} \left( \frac{i_{T,t+1}}{i_{T,t}} - 1 \right) \left( \frac{i_{T,t+1}}{i_{T,t}} \right)^2 \right] \end{aligned} \quad (\text{A.26})$$

$$\frac{\tilde{y}_{O,t}}{\tilde{y}_O} = \left( \frac{\tilde{y}_{O,t-1}}{\tilde{y}_O} \right)^{\rho_{yo}} \exp(\varepsilon_t^{yo}) \quad (\text{A.27})$$

$$\frac{p_{O,t}^*}{p_O^*} = \left( \frac{p_{O,t-1}^*}{p_O^*} \right)^{\rho_{po}} \exp(\varepsilon_t^{po}) \quad (\text{A.28})$$

$$y_{O,t} = s_t p_{O,t}^* \tilde{y}_{O,t} \quad (\text{A.29})$$

$$y_t = p_{N,t} y_{N,t} + s_t y_{T,t} + y_{O,t} \quad (\text{A.30})$$

$$t_t^O = \tau^O s_t p_{O,t}^* \tilde{y}_{O,t} \quad (\text{A.31})$$

$$R_{dc,t-1} = R^f + v_{dc} \exp \left[ \eta_{dc} \left( \frac{d_t + d_{c,t}}{y_t} - \frac{d + d_c}{y} \right) \right] \quad (\text{A.32})$$

$$g_t = \left[ \nu_t^{\frac{1}{\chi}} (g_{N,t})^{\frac{\chi-1}{\chi}} + (1 - \nu_t)^{\frac{1}{\chi}} (g_{T,t})^{\frac{\chi-1}{\chi}} \right]^{\frac{\chi}{\chi-1}} \quad (\text{A.33})$$

$$g_{N,t} = \nu_t \left( \frac{p_{N,t}}{p_t^G} \right)^{-\chi} g_t, \quad g_{T,t} = (1 - \nu_t) \left( \frac{s_t}{p_t^G} \right)^{-\chi} g_t \quad (\text{A.34})$$

$$p_t^G = \left[ \nu_t p_N^{1-\chi} + (1 - \nu_t) s_t^{1-\chi} \right]^{\frac{1}{1-\chi}} \quad (\text{A.35})$$

$$\nu_t = \frac{(p^G g) \nu + (p_t^G g_t - p^G g) \nu_g}{p_t^G g_t} \quad (\text{A.36})$$

$$\tilde{g}_t^I = \left\{ \begin{array}{ll} \bar{\epsilon} g_t^I, & \text{if } \bar{\gamma}_t^{GI} \leq \bar{\gamma}^{GI} \\ \bar{\epsilon} (1 + \bar{\gamma}^{GI}) \bar{g}^I + \epsilon (\bar{\gamma}_t^{GI}) [1 + \bar{\gamma}_t^{GI} - \bar{\gamma}^{GI}] \bar{g}^I, & \text{if } \bar{\gamma}_t^{GI} > \bar{\gamma}^{GI} \end{array} \right\} \quad (\text{A.37})$$

$$\epsilon (\bar{\gamma}_t^{GI}) = \exp [-\varsigma_\epsilon (\bar{\gamma}_t^{GI} - \bar{\gamma}^{GI})] \bar{\epsilon} \quad (\text{A.38})$$

$$k_{G,t} = (1 - \delta_{G,t}) k_{G,t-1} + \tilde{g}_t^I \quad (\text{A.39})$$

$$\delta_{G,t} = \left\{ \begin{array}{ll} \phi \delta_G \frac{\delta_G k_{G,t-1}}{\tilde{g}_t^I}, & \text{if } \tilde{g}_t^I < \delta_G k_{G,t-1} \\ \rho_\delta \delta_{G,t-1} + (1 - \rho_\delta) \delta_G, & \text{if } \tilde{g}_t^I \geq \delta_G k_{G,t-1} \end{array} \right\} \quad (\text{A.40})$$

$$f_t^* - f^* = \max \left\{ f_{floor} - f^*, (f_{t-1}^* - f^*) + \frac{f_{in,t}}{s_t} - \frac{f_{out,t}}{s_t} \right\} \quad (\text{A.41})$$

$$gap_t = \Delta b_t + s_t \Delta d_{c,t} + (\tau_t^C - \tau^C) c_t + (\tau_t^L - \tau^L) w_t l_t - p_t^G (g_t^C - g^C) - (z_t - z) \quad (\text{A.42})$$

$$\begin{aligned} f_{in,t} = & \tau^C c_t + \tau^L w_t l_t + (1 - \vartheta^K) \tau^K (r_{T,t}^K k_{T,t-1} + r_{N,t}^K k_{N,t-1}) + t_{O,t} + \mu k_{G,t-1} \\ & + s_t a_t^* + s_t g r_t^* + s_t (R^{RF} - 1) f_{t-1}^* + s_t \Delta d_t \end{aligned} \quad (\text{A.43})$$

$$f_{out,t} = p_t^G g_t^I + p_t^G g^C + z + (s_t R_d - 1) d_{t-1} + (R_{dc,t-1} - 1) s_t d_{c,t-1} + (R_{t-1} - 1) b_{t-1} \quad (\text{A.44})$$

$$\varkappa \Delta b_t = (1 - \varkappa) s_t \Delta d_{c,t} \quad (\text{A.45})$$

$$\tau_{\text{target},t}^C = \tau^C + \lambda_1 \frac{gap_t}{c_t} \quad (\text{A.46})$$

$$g_t = g_t^I + g_t^E + g_t^H \quad (\text{A.47})$$

$$\tau_t^C = \min \{ \tau_{\text{rule},t}^C, \tau_{\text{ceiling}}^C \} \quad (\text{A.48})$$

$$\tau_{\text{rule},t}^C = \tau_{t-1}^C + \zeta_1 (\tau_{\text{target},t}^C - \tau_{t-1}^C) + \zeta_2 (x_{t-1} - x), \quad \text{with} \quad \zeta_1, \zeta_2 > 0 \quad (\text{A.49})$$

$$y_{N,t} = \varphi p_{N,t}^{-\chi} (c_t + i_{N,t} + i_{T,t}) + \nu_t \left( \frac{p_{N,t}}{p_t^G} \right)^{-\chi} g_t \quad (\text{A.50})$$

$$\frac{ca_t^d}{s_t} = g r_t^* - \Delta f_t^* + \Delta d_t + \Delta d_{c,t} + \Delta b_t^* \quad (\text{A.51})$$

$$\begin{aligned} ca_t^d = & c_t + i_{N,t} + i_{T,t} + p_t^G g_t + \Theta_t^{OPT*} - y_t - s_t r m_t^* + (R_d - 1) s_t d_{t-1} \\ & + (R_{dc,t-1} - 1) s_t d_{c,t-1} + (R_{t-1}^* - 1) s_t b_{t-1}^* - (R^{RF} - 1) s_t f_{t-1}^* \end{aligned} \quad (\text{A.52})$$

$$g_t = g_t^I + g_t^E + g_t^H \quad (\text{A.53})$$

$$A_{j,t} = z_{j,a} e_t^{\beta_{j,E}} h_t^{\beta_{j,H}} \quad (\text{A.54})$$

$$e_t = (1 - \delta_E) e_{t-1} + (\gamma^E g_{t-j_E}^E)^{\psi_E} \quad (\text{A.55})$$

$$h_t = (1 - \delta_H) h_{t-1} + (\gamma^H g_{t-j_H}^H)^{\psi_H} \quad (\text{A.56})$$

$$g_t^E = \phi_t^E g_t \quad (\text{A.57})$$

$$g_t^H = \phi_t^H g_t \quad (\text{A.58})$$

$$g_t^K = (1 - \phi_t^H - \phi_t^E) g_t \quad (\text{A.59})$$

$$\phi_t^E = \begin{cases} \phi_{init}^E & \text{for } t = 0 \\ \phi_{new}^E & \text{for } t > 0 \end{cases} \quad (\text{A.60})$$

$$\phi_t^H = \begin{cases} \phi_{init}^H & \text{for } t = 0 \\ \phi_{new}^H & \text{for } t > 0 \end{cases} \quad (\text{A.61})$$