The Dynamics of Corruption and Unemployment in a Growth Model with Heterogeneous Labour

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Abstract

This paper presents an overlapping generations growth model with heterogeneous labour, endogenous unemployment, and public sector corruption. Unlike most previous studies, the model does not separate public officials and private individuals into two distinct groups. Instead, taking up bureaucratic appointment as a public servant is modelled as an occupational choice, which then allows for the endogenous determination of the proportion of public officials, the share of corrupt officials among them, and the public investment efficiency of the economy within the dynamic system. Parameterised for Nigeria, the dynamics of endogenous corruption and unemployment, as well as their policy tradeoff, are studied using numerical policy experiments based on relevant themes in the country, which include public sector downsizing and social intervention schemes.

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1 Introduction

In most developing economies, notably low and lower–middle income economies with poor institutional and governance quality, public officials, often well-educated groups of elites, are in unique positions to abuse their powers in the various forms of corruption. Public sector corruption, broadly defined as the illegal or unauthorised profiteering by public officials abusing their authoritative positions, can manifest in different forms—including embezzlement of public funds, fraud claims, and direct receipts of bribery—and offers substantial personal gains at the costs of society, hence potentially causing significant damage to socio- and economic development (Blackburn et al., 2011).

In the literature of public sector corruption, the contributions made in the form of microeconomic and applied empirical studies over the last decade have been enormous[1], with development economists now having a general consensus on the bads of corruption and its long-term adverse impact of growth and development. Indeed, corruption activities often transcend direct practicing of fraud and bribery, and in some instances lead to the creation of bureaucratic leviathan or red tapes, especially when there are principal-agent considerations in the duties of public officials (Banerjee, 1997; Guriev, 2004; Fredriksson, 2014). As such, corruption can be persistent over time, hence adversely affecting for instance, private investment (Mauro, 1997), human capital accumulation (Ehrlich and Liu, 1999), firms' growth (Fisman and Svensson, 2007), and inequality (Blackburn and Forgues-Puccio, 2007) over the long-run. These are supported by findings in the vast empirical literature, where evidence shows that most developing countries with poor institutions and high

[1]Examples of microeconomic models with public sector rent-seeking and corruption include, non-exhaustively, Cule and Fulton (2005), Infante and Smirnova (2009), Dugrov (2010), Ryvkin and Serra (2012), Fredriksson (2014), and relevant references therein. These studies examine corruption manifesting in different forms, but not their implications to economic growth in a general equilibrium, macroeconomic context.

levels of corruption have experienced poor growth performance. For instance, Mauro (1997) documents evidence that corruption tends to lead to a diversion of public expenditure from growth-promoting areas such as education and healthcare to large-scale infrastructure investment projects. Moreover, the adverse effects of corruption on growth are shown by Aidt et al. (2008) and Méndez and Sepúlveda (2006) to be both nonlinear and non-monotonic, with the latter documenting the existence of non-zero level of corruption in a growth-maximising situation.

In spite of the growing research interests on corruption and growth, there remains some relatively underexplored areas. One such aspect that have plenty of anecdotal evidence and often attract attention from development practitioners and low-income countries' policymakers alike yet receive little attention from the academic community is the corruption-unemployment nexus. As argued by the World Bank (in its periodic updates on the regions) and in contributions such as Ndikumana (2006) and Bakare (2011), both corruption and unemployment are often two of the most pressing policy issues facing many African developing economies. High levels of corruption in African countries reduces the quality of public investment, discourages private physical and human capital investment, and consequently results in dampened growth, which in turn perpetuates unemployment. Sustained unemployment then results in economic instability and an increase in illegal activities (often in the forms of black market), which then making it easier and cheaper for corruption practices. Indeed, faced with a weakened economy with large gaps in infrastructure, a lack of skills, and poor public service delivery, the goals of fighting corruption and tackling unemployment are among the main policy priorities of the new Buhari administration in Nigeria, one of the largest lower-middle income economy in Sub-Saharan Africa.

While the corruption-unemployment nexus remains an underexplored area, more so in macroeconomic studies, we can easily conjecture a dynamic relationship between the two by reviewing the existing literatures in these two areas. In terms of macroeconomic contributions on corruption, the earlier study of Sarte (2000) models corruption in the form of bureaucratic rent-seeking, where the bureaucrats restrict firms' entry into the formal sector by creating artificial procedures as means to appropriate firms' profits. Subsequent contributions with rent-seeking bureaucrats exploiting their access to asymmetric information tend to come to a conclusion that corruption leads to adverse effects on the quality of public capital, discourage specialisation and therefore leading to lower economic growth. These include Bose et al. (2008) and Chakraborty and Dabla-Norris (2011). Given that the procurement process is said by the former to account for nearly 70 percent of many central government's expenditure, a popular modelling choice therefore involves specification of public officials having asymmetric information on the quality and cost of inputs necessary for public goods production, which then creates opportunities for officials to embezzle public funds (Blackburn et al., 2011; Haque and Kneller, 2015).

In terms of studies focusing on structural unemployment and economic growth, Bernal-Verdugo et al. (2012) argue that policies aimed at increasing labour market flexibility would reduce unemployment. For developing economies with well-documented poor governance and public service deliver issues, Agénor et al. (2007), in a computational general equilibrium study on Middle East and North Africa, argue for the use of labour policies to not only reduce unemployment but also to indirectly improve the governance effectiveness (given that public sector is often one of the largest employer in these economies). Similar findings are documented by Anand and Khera (2016), who study the impact of labour market reforms on unemployment and informality in India. However, in the context of middle-income economies, Agénor and Lim (2017) conclude their study by stating that ambitious labour market measures aimed at tackling long-term unemployment can be fruitless if there were weak administrative capacity and poor governance, both of which are hallmarks of economies with high incidence of corruption.

Empirically, to our knowledge, Bouzid (2016) is the only study that examines the nexus between corruption and unemployment—albeit youth unemployment—in which he posits that corruption practices by public officials with hiring power tend to increase the unemployment rate among youth and educated workers, and this in turn results in more corruption when job-seekers have to bribe the officials for job. Lackó (2004) indirectly examines this nexus between corruption and unemployment, where a high labour tax combined with high corruption level is found to contribute to an increase in unemployment. Nevertheless, these empirical exercises are neither anchored by microfoundations nor general equilibrium framework. As such, what we do know about the nexus is that, there appears to be non-direct but significant relationship between corruption and unemployment. As implied in reports such as World Bank (2012), the effects of corruption on unemployment tends to be indirect, where the reduced public investment quality results in lower growth and income, which in turn impedes job creation in the long-run. Nonetheless, the implementation of effective labour policies can facilite human capital development, improve social cohesion, and consequently reduce the incentive for corruption.

To formally model the corruption-unemployment nexus, this paper presents a dynamic ovelapping generations (OLG) growth model with endogenous unemployment and public sector corruption. In terms of existing studies, Spinesi's (2009) model with heterogeneous abilities and endogenous human capital accumulation examines many of the issues that we are modelling. However, his model is based on a Schumpeterian quality ladder framework without unemployment and does not examine transitional dynamics. In contrast, we have a different setup that allows for endogenous determination of both unemployment and corruption, as well as the examination of transitional dynamics of policies. Also, unlike with standard theoretical growth models of corruption, we do not need to separate public officials and private individuals into two distinct groups. Instead, taking up bureaucratic appointment as a public servants is modelled as an occupational choice—albeit one that has specification that ensures complete bureaucratic participation—which then allows for the proportion of public officials in the economy in each period, as well the shares among those that are corrupt, to be endogenously determined. In my knowledge, this is among the first instances where the dynamics of endogenous corruption and unemployment are examined together in a model of endogenous growth. As multilateral organisations alike have moved forward with designing more concrete measurement of corruption, this allows us to provide a direct theoretical counterpart where variables such as the share of corrupt officials and public investment efficiency can be directly parameterised and studied as policy variables.

The remainder of the paper is organised as follows. Section 2 presents the model. Section 3 defines the balanced growth equilibrium and discusses its properties. Model parameterisations are reported in Section 4 to reflect the initial state of a typical lower-middle income Sub-Saharan African economy facing high rates of unemployment and corruption. Specifically, the model is parameterised for Nigeria, which is topical given that the new administration is committed to fighting corruption. In Section 5, various policy experiments are analysed and discussed. Section 6 concludes the paper.

2 The Model

Time is discrete with $t = 0, 1, ..., \infty$, and there is an overlapping generations of households populated by two-periods lived individuals (adulthood and old age) with different innate abilities. Population is constant at $\bar{N}$. Each individual is risk neutral and endowed with one unit of time in each period of life. In old age, time is allocated entirely to leisure. In the beginning of adulthood, individuals decide whether to acquire skills or to directly enter into the workforce as unskilled workers. The acquisition of skills is necessary if one were to work as public officials, or skilled workers in the private sector (specifically, non-routine task in the design sector). Both the unskilled and skilled workers can be unemployed, of which then they collect an unemployment benefit/cash transfer from an unemployment insurance fund financed by firms' payroll contribution and administered by the government. In addition, the government also operates a general budget, where expenditure consists primarily of public invesment and public emoluments. The latter consists of the wages paid to the public officials employed to procure for public capital goods using funds allocated from the former. Corruption arises from the incentive of an official to appropriate public funds by falsifying information to the government. Lastly, the private production sectors consist of a final good sector and a consolidated intermediate goods and design sector. Unemployment prevails in the economy due to labour market imperfection asociated with union bargaining of wages.

In terms of existing studies, the unemployment and private sector aspects of the model are most similar to Agénor and Lim (2017), while the public sector features the "corruption due to uncertainty associated with procurement costs" attributes introduced initially in Bose et al. (2008), and subsequently modified by Blackburn et al. (2011) and Haque and Kneller (2015).

2.1 Individuals

Individuals have identical preferences but are born with different abilities, indexed by a. Ability is instantly observable by all and follows a continuous distribution with density function $f(a)$ and cumulative distribution function $F(a)$, with support $(0, 1)$. For tractability, a is assumed to be uniformly distributed on its support. Each individual maximises utility and decides whether to engage in market work as an unskilled worker or (after spending $1-\varrho$ to acquire skills) as a skilled worker. Specifically, an adult with ability a can enter the labour force at the beginning of period t as an unskilled worker and earn the net wage $(1-\tau)w_t^U$, which is independent of the worker's ability. Alternatively, the individual may choose to first spend a fraction $\varrho \in (0,1)$ of his/her time endowment at the beginning of adulthood in advanced training, incur a cost $tc_t > 0$, and then enter the labour force for the remainder of the period as a skilled worker, either working in the private sector as a design worker, or in the public sector as a public official. The former earns after-tax wage of $(1-\tau)w_t^S$, while the latter earns non-taxable wage, w_t^S. During training, workers earn no income. All individuals can either be employed (superscript E) or unemployed (superscript L). If unemployed, individuals earn an unemployment benefit/cash transfer from the government, b_t, which is not taxable.

Let $c_{t|t+n}^{h,j}$ denote consumption at period $t+n$ of an individual $h = U, SY, SG$, either employed or unemployed, $j = E, L$, born at the beginning of period t, with $n = 0, 1$. The individual's discounted utility function is given by

$$V_t^{h,j} = \eta_C \ln c_{t|t}^{h,j} + \frac{\ln c_{t|t+1}^{h,j}}{1+\rho}, \ h = U, SY, SG, \quad j = E, L \tag{1}$$

where $\rho, \eta_C > 0$ are the common discount rate and preference parameter, respectively.[2]

Generally, in the absence of corruption possibility, the period-specific budget constraints are given by

$$c_{t|t}^{U,j} + s_t^{Uj} = \begin{cases} (1-\tau)w_t^U & \text{if } j = E \\ b_t & \text{if } j = L \end{cases}, \tag{2}$$

[2]Individuals do not derive disutility (utility) from working (leisure). The opportunity cost of unemployment is simply the wage foregone.

$$c_{t|t}^{S,j} + s_t^{S,j} = \begin{cases} (1-\tau)[(1-\varrho)w_t^S - tc_t] & \text{if } h = SY,\ j = E \\ (1-\varrho)b_t - tc_t & \text{if } j = L \\ (1-\varrho)w_t^S - tc_t & \text{if } h = SG, j = E \end{cases} \tag{3}$$

$$c_{t|t+1}^{h,j} = (1 + r_{t+1})s_t^h, \quad h = U, SY, SR, \quad j = E, L \tag{4}$$

where $s_t^{h,j}$ is savings, $1 + r_{t+1}$ the gross rate of return between periods t and $t+1$, and $\tau \in (0,1)$ the tax rate.

Note that the budget constraint specified above for a public official applies only to non-corrupt officials, since at the point when training decision would have to be made, an individual does not factor into the possibility of a corruption opportunity arisen when he has been employed as a public official. As such, an individual finds it optimal to train if and only if his expected (after-tax) earnings as a skilled worker, adjusted for the time and pecuniary costs of training, exceeds the expected earnings of an unskilled worker:

$$(1-\varrho)(\zeta_t^{SY}(1-\tau)w_t^S + \zeta_t^{SG}w^S + \zeta_t^{SL}b_t) - tc_t \geq (1-\zeta_t^{UL})(1-\tau)w_t^U + \zeta_t^{UL}b_t, \tag{5}$$

where the going wage, or the unemployment benefit, is weighted by the respective probability of being either employed or unemployed, $\zeta_t^h \in (0,1)$, for $h = SY, SG, SL, UY, UL$.[3] In specifying (5), we assume for simplicity that an individual knows if his/her ability is above or below the threshold a^C and can therefore decide whether to acquire skilled skills or not at the beginning of adulthood.

The training cost is proportional to the expected skilled wage when employed and varies inversely with the individual's ability, which determines how fast (or how well) he or she can learn:

$$tc_t = \mu(1-\varrho)(\zeta_t^{SY}(1-\tau)w_t^S + \zeta_t^{SG}w_t^S)/a^\chi, \tag{6}$$

with $\mu, \chi \in (0,1)$. The assumption on the productivity parameter χ ensures that the effect of ability on training costs is subject to diminishing returns.

[3] Equation (5) is assumed to hold as a strict inequality for the individual with the highest ability, that is, $a = 1$, otherwise nobody would choose to become skilled

As shown in the Appendix, the threshold level of ability a_t^C such that all individuals with ability higher than a_t^C choose to undergo training is given by

$$a_t^C = \mu^{1/\chi}\left\{1-(1-\varrho)^{-1}\frac{(1-\zeta_t^{UL})(1-\tau)w_t^U+\zeta_t^{UL}b_t-(1-\varrho)\zeta_t^{SL}b_t}{\zeta_t^{SY}(1-\tau)w_t^S+\zeta_t^{SG}w_t^S}\right\}^{-1/\chi}. \tag{7}$$

The productivity of unskilled workers is constant regardless of ability and is normalised to unity. Given (7), the raw supply of unskilled labour, N_t^U, is equal to the number of individuals in the population who choose not to undergo training:

$$N_t^U = \bar{N}\int_0^{a_t^C} f(a)da = a_t^C\bar{N}. \tag{8}$$

The raw supply of skilled workers, at any time t, is $\bar{N}\int_{a_t^C}^1 f(a)da = (1-a_t^C)\bar{N}$. However, the average skill level of workers with ability $a \in (a_t^C, 1)$ who have undergone training equals $(a_t^C+1)/2$; thus, the effective supply of skilled labour at time t, can be defined as

$$N_t^S = \frac{1-(a_t^C)^2}{2}\bar{N}. \tag{9}$$

2.2 Final Good

The final good production is characterised by routine task. Firm i, Y_t^i, requires the use of unskilled labour, $N_{i,t}^{UY}$, private capital, $K_{i,t}^P$, a combination of intermediate inputs, $x_{i,s,t}$, $s \in (0, M_t)$, and aggregate public capital, K_t^G.

The production function is specified as

$$Y_t^i = [\frac{K_t^P}{\bar{N}\zeta}]^{\iota}(N_{i,t}^{UY})^{\beta^U}(K_{i,t}^P)^{\alpha}[\int_0^{M_t} x_{i,s,t}^{\eta}ds]^{\gamma/\eta}(K_t^G)^{\varpi}, \tag{10}$$

where $\beta^U, \alpha, \gamma \in (0,1)$, $\omega > 0$, $\beta^U+\alpha+\gamma = 1$, $\eta \in (0,1)$ and $1/(1-\eta) > 1$ is (the absolute value of) the price elasticity of demand for each intermediate good, and K_t^P is the aggregate private capital. Constant returns prevail with respect to private inputs, and production is subject to a standard Arrow-Romer type of externality associated with the aggregate private capital stock, though subject to congestion by the total population size at $\zeta > 0$.

Assuming full depreciation, firm i's profits are defined as

$$\Pi^Y_{i,t} = Y^i_t - \int_0^{M_t} P^s_t x_{i,s,t} ds - w^U_t N^{UY}_{i,t} - r_t K^P_{i,t}. \tag{11}$$

Each firm maximises profits subject to (11) with respect to labour, private capital, and quantities of intermediate goods $x_{i,s,t}$, $\forall s$, taking factor prices and M_t as given. This yields, in standard fashion,

$$w^U_t = \beta^U \frac{Y_{i,t}}{N^{UY}_{i,t}}, \tag{12}$$

$$r_t = \alpha(\frac{Y_{i,t}}{K^P_{i,t}}). \tag{13}$$

$$x_{i,s,t} = (\frac{\gamma Z_{i,t}}{P^s_t})^{1/(1-\eta)}, \quad s = 1, ...M_t, \tag{14}$$

$$Z_{i,t} = Y_{i,t} / \int_0^{M_t} (x_{i,s,t})^\eta ds. \tag{15}$$

2.3 Intermediate Goods and Designs

A Romerian specification is used for the intermediate goods sector, where monopolistically competitive market structure is assumed. To produce an intermediate variety, a corresponding design has to be purchased from a counterpart design firm. The design firms are the private sector employers of skilled labour in this economy. There is only one producer of each input s, and each of them must pay a fee to use the design. Production of each unit of an intermediate good uses a single unit of the final good. Each intermediate good producer sets a price to maximise profits, given the perceived demand function for its good. With a standard optimal price of $P^s_t = \frac{1}{\eta}$. $\forall s = 1, ...M_t$, the quantity demanded at this price is $x_{s,t} = (\gamma\eta Z_t)^{1/(1-\eta)}$, $\forall s$, which under symmetry $\int_0^{M_t} x_{s,t}^{\eta} ds = M_t x_t^{\eta}$, yields

$$x_t = \gamma\eta(\frac{Y_t}{M_t}), \tag{16}$$

with maximum profit of

$$\Pi_t^I = (1-\eta)\gamma(\frac{Y_t}{M_t}). \tag{17}$$

Following Agénor and Canuto (2015), intermediate firms are assumed to last only one period, and that patents are auctioned off randomly to a new group of firms in each period. Thus, each producer of a new intermediate good holds a patent only for the period during which it is bought, implying monopoly profits during that period only; yet patents last forever. By arbitrage, therefore,

$$Q_t = \Pi_t^I. \tag{18}$$

Meanwhile, firms engaged in design generate blueprints for new intermediate goods, using the same technology. Each firm produces a single design and there is no aggregate uncertainty. The aggregate stock of designs evolves according to

$$M_{t+1} - M_t = (\frac{K_t^G}{K_t^P})^{\varsigma_1^m} M_t \frac{(1-\varrho)N_t^{SY}}{\bar{N}}, \tag{19}$$

which uses skilled workers, and depends on the public-private capital ratio (Agénor and Alpaslan, 2014) and the stock of designs (Jones, 2005). To eliminate scale effects, it is the ratio of workers to total population that is specified in the production function[4]

Profit maximisation by the design firms (by selecting N_t^{SY}) involves maximising $\Pi_t = Q_t(M_{t+1} - M_t) - [w_t^S(1-\varrho)N_t^{SY}]$ subject to the skilled wage, yields a first-order condition of

$$w_t^S = \frac{Q_t(k_t^G)^{\varsigma_1^m} M_t}{N_t^{SY}}, \tag{20}$$

[4]See Dinopoulos and Segerstrom (1999).

where $k_t^G = K_t^G / K_t^P$. In turn, by substituting in the expression for Q_t, the skilled wage in the private sector is given by

$$w_t^S = \frac{[(k_t^G)^{\varsigma_1^m}(1-\eta)\gamma]Y_t}{N_t^{SY}}. \quad (21)$$

2.4 Wages-Setting

To obtain a model equilibrium with non-zero unemployment, we adopt the straightforward labour market institution of a *right-to-manage* union bargaining framework. Following Agénor and Lim (2017), two separate but similar unions exist—one each for the unskilled and skilled workers in the private sector—where the wage-setting process takes place between a centralised trade union and firms. The unions' objectives are to maximise the expected current income of its members, subject to wage and employment targets, taking the existing capital stock (for unskilled) and design stock (for skilled) as given. The unions therefore do not internalise the effect of future wages on the firm's decision to accumulate capital—and thus future labour demand, effectively making it a static optimisation problem at every period t.[5]

Specifically, for $h = UY, SY$, the union sets w_t^U or w_t^S with the objective of maximising a utility function that depends on deviations of both employment and wages from their target levels, subject to the labour demand schedule for each type. Normalising the employment target to zero, the union's utility function takes the standard form

$$\mathfrak{V}_t^h = (w_t^h - w_t^{hT})^{\xi^h} (N_t^h)^{1-\xi^h}, \quad (22)$$

[5] An alternative specification is to consider a Nash wage bargaining process, in which case then the labour demand is derived from the bargaining process instead of firms' profit maximisation decision. However, given that the two types of workers work in different sectors, and that the difference in bargaining features will not result in significant difference to the unemployment-corruption nexus, we use the more convenient *right-to-manage* model where unions set wage taking labour demand schedule of firms as given. See Bhattacharyya and Gupta (2015) for a direct comparison of the two specifications.

where $h = UY, SY$, $^h \in (0,1)$, and N_t^h is given in (12). The term w_t^{hT} measures the union's target wage, whereas ^{h} reflects the relative importance that the union attaches to wage deviations from that target.

Maximising (22) with respect to w_t^h gives the actual wage as a mark-up (which is increasing in ^{h}) over the target wage, we get

$$w_t^h = (\frac{1-\xi^h}{1-2\xi^h})w_t^{hT}. \tag{23}$$

We specify the target wages to be linearly dependent on the minimum level of income a worker would otherwise earn if unemployed, b_t, adjusted (negatively) to the unemployment rate of the respective category of workers, as in

$$w_t^{hT} = b_t(\theta_t^h)^{-\varkappa^h} w_0^h, \quad h = UL, SL \tag{24}$$

where $\varkappa^{UL}$, $\varkappa^{SL} > 0$, w_0^h and θ_t^h, $h = UL, SL$ denote a shift parameter and the unemployment rate (in proportion of $\bar{N}$) of labour category h, with

$$b_t = \kappa_t \frac{Y_t}{\bar{N}}, \tag{25}$$

where $\kappa_t > 0$ is an endogenously determined (by the government's allocation) benefit/social security indexation ratio variable. Consistent with most specification, it is also indexed to the level of per capita income in each period t.[6,7]

Using (23), (24), and (25), we can derive an alternative expression for w_t^U

[6] Unlike Agénor and Lim (2017), which focuses on examining the impacts of various labour market policies in developed and upper-middle income economies, the focus of this paper, the corruption-unemployment nexus, is usually more relevant in a developing economy context—most of which have non-binding minimum wage and unemployment benefits. As such, b_t in this context can be interpreted as some form of social security payment or cash transfers to meet the minimum income of the unemployed.

[7] In relatively parsimonious partial equilibrium model, such as Heer and Morgenstern (2005), the unemployment benefit is indexed to previous period's earnings. While our indexation is to the same-period income per capita, κ_t is endogenous here, which then allows for much richer dynamic feedback from the system into the benefit indexation.

and w_t^S, as in

$$w_t^U = \kappa_t(\frac{1-\xi^U}{1-2\xi^U})w_0^U(\frac{Y_t}{\bar{N}})(\theta_t^{UL})^{-\varkappa^U}, \tag{26}$$

and

$$w_t^S = \kappa_t(\frac{1-\xi^S}{1-2\xi^S})w_0^S(\frac{Y_t}{\bar{N}})(\theta_t^{SL})^{-\varkappa^S}, \tag{27}$$

respectively.

2.5 Public Sector

Based on the public procurement framework of Blackburn et al. (2011) and Haque and Kneller (2015), the government is specified to hire public officials (paying non-taxable market salary, w_t^S) to procure capital goods to be used for public investment. All public officials are assumed to be corruptible in this model, though given the non-taxable nature of income, skilled labour hired as public officials will always prefer to work for the government than in the private sector. This ensures the allocation of talent condition in Acemoglu and Verdier (1998) would hold, as the government can ensure complete bureaucratic participation just by paying the skilled market wage, w_t^S. As shown later, to finance the public officials' salaries, the government allocates a constant fraction, υ_G, of the government revenue each period as public emoluments.

On aggregate, the government demands g_t amount of capital goods, which is a constant fraction of the final output in the economy, ψY_t (Blackburn et al. 2010; Blackburn et al. 2011; Haque and Kneller 2015). For convenience, we assume that the government sets ψ in accordance to the initial public capital-final output ratio, K_0^G/Y_0, hence $\psi = K_0^G/Y_0$, and keeps this ratio constant over time. As such, in an economy with corruption and leakages, there is a gap between the aggregate public capital level demanded by the government for the economy and the actual supply of the public capital-final output ratio in each period t, K_t^G/Y_t, due to corruption.[8]

[8] As would be seen in the policy experiments later, we analyse an additional case where

Each public official is responsible to procure g_t/N_t^{SG} units of capital goods and claim the corresponding spending off the total governmental allocation to public infrastructure investment. In each period t, due to an imperfect monitoring effort made by the government, it is assumed, for simplicity, that a corrupted public official faces a random probability, $p \in (0, 1)$ of avoiding being caught, and probability, $1 - p$, of being caught. Public officials being caught are fined the full amount of his wage income, therefore left with zero income.[9]

Based on similar interpretation of Chakraborty and Dabla-Norris (2011), public investment projects are assumed to yield high- or low-quality of public capital, and this partially depends on the capital goods purchase decisions made by the public officials. A low-quality purchase yields only $\Upsilon < 1$ units of productive capital good despite costing 1 unit of good. A high-quality purchase always yields 1 unit of productive capital good, though it is subject to different cost, indexed by ϕ. ϕ assumes a uniform distribution with support $(1, \phi^{\max})$. The government is aware of the overall distribution of the cost, though it does not observe the true cost and quality of the goods procured, therefore have to rely on the public officials for information. As such, similar to Haque and Kneller (2015), potential corruption opportunity arises because an official can falsify information by over-reporting the unit cost. However, unlike their binary specification, ϕ is a continuous distribution, which later

ψ_t is endogenous and varies over time. In this case, the government is assumed to attempt to close the gap between the aggregate demand and supply of public capital good-to-final output ratio by resetting its demand in each period.

[9]The benchmark simplication approach to the government's monitoring technology is simply adopted from Blackburn et al. (2011) and Haque and Kneller (2015). In line with the standard Shapiro-Stiglitz shirking model, this means the probability of being detected is related one-to-one with the monitoring intensity (see van Schaik and de Groot (2000) for an example). Thus, although given at the level of each individual public official, it is in principle treated as a choice variable by the government, which would normally vary with unit monitoring costs. Later, for the purposes of sensitivity analysis, this probability of getting caught–hence the monitoring intensity–is endogenised and allowed to vary across time, depending on the total share of corrupt individuals in the economy, $\varepsilon_t N_t^{SG}/\bar{N}$.

allows us to model the share of corrupt officials endogenously. Plus, a corrupt official will not be able to claim the maximum amount, $\phi^{\max}$, because the government knows the upper bound ϕ, therefore will always claim his/her respective optimal cost at time t, ϕ_t.

A public official that is not corrupt is always going to maximise public capital good quality per unit of expnditure. Specifically, the official procures g_t/N_t^{SG} units of capital goods (with quality g_t/N_t^{SG}) at the actual realised cost. On average, if no one is corrupt in the economy, the claim made by a public official is therefore $\bar{\phi} = (1+\phi^{\max})/2$. In this instance, a public official will therefore earn $(1-\varrho)w_t^S$ (recall that ϱ has been spent in acquiring skills). However, there is corruption opportunity due to the uncertainty associated with the cost. If a public official were to be to corrupt, he/she procures g_t/N_t^{SG} units of capital goods (but with low-quality, $\Upsilon[g_t/N_t^{SG}]$). On average, a corrupt official spends $\bar{\phi}$ per unit ($\bar{\phi}[g_t/N_t^{SG}]$), but claims the optimal amount, $\phi_t \in (\bar{\phi}, \phi^{\max})$, making a personal gain of $(\phi_t - \bar{\phi})[g_t/N_t^{SG}]$ on top of the wage[10].

For a corrupt public official, with an exogenous probability $1-p$, the official is apprehended and confiscated of all his income. With a probability p, the official succeeds in evading detection and therefore has an income of $[(1-\varrho)w_t^S - tc_t] + (\phi^{optimal} - \bar{\phi})[g_t/N_t^{SG}] - hc_t$. As such, a public official will embezzle the public funds if his/her expected payoff is at least as good as not doing so. This gives

$$p\left[((1-\varrho)w_t^S - tc_t) + (\phi_t - \frac{1+\phi^{\max}}{2})\frac{g_t}{N_t^{SG}} - hc_t\right] \geq (1-\varrho)w_t^S - tc_t, \quad (28)$$

where hc_t is the resources spent by a corrupt official to attempt to conceal his/her behaviour. Similar to Haque and Kneller (2015), hc_t is assumed to be

[10] By implication, in the context of studies such as Blackburn et al. (2011) and Haque and Kneller 2015), this is similar to saying that those public officials whose actual realised cost falls between $\bar{\phi}$ and $\phi^{\max}$ is corruptible, while those facing cost below $\bar{\phi}$ is non-corruptible.

an increasing function of the illegal income, $(\phi_t - \bar{\phi})(g_t/N_t^{SG})$, given by

$$hc_t = \left(\frac{\theta_t^{SL}}{\theta_t^{UL}}\right)^{\delta} (\phi_t - \frac{1+\phi^{\max}}{2}) \frac{g_t}{N_t^{SG}}, \tag{29}$$

where $\delta > 0$. Unlike their specification, the concealment cost does not depend on the share of corrupt officials (ε_t), which is endogenous in this model[11]. Instead, it depends on the ratio of skilled over unskilled unemployment rate in the economy, which is a novel feature of this model. The former is consistent with the *uemployment-as-disciplinary device* specification of most Shapiro-Stiglitz type of models, where the higher the skilled unemployment rate is, the more costly for an official to corrupt, hence the concealment cost. In contrast, the higher the unskilled unemployment rate is in the economy, it is easier/cheaper for the corrupt officials to conceal their behaviours, which is consistent with the informal sector interpretation that sustained unemployment tends to translate to an increase in hidden economic activities—arena where embezzled funds can be concealed.

Holding the incentive condition (28) in equality, and using $g_t = \psi Y_t$, (6), (12), (29), we can derive a threshold value for the unit cost, ϕ_t^*, above which a public official will choose to be corrupt:

$$\phi_t^* = \bar{\phi} + \frac{(1-p)}{p}\left[1 - \frac{\mu}{a_t^{\chi}}(\zeta_t^{SY}(1-\tau) + \zeta_t^{SG})\right](1-\varrho)\Phi_t\psi^{-1}\frac{N_t^{SG}}{N_t^{SY}}\left[1 - \left(\frac{\theta_t^{SL}}{\theta_t^{UL}}\right)^{\delta}\right]^{-1}, \tag{30}$$

where $\Phi_t = [(k_t^G)^{\varsigma_1^m}(1-\eta)\gamma]$.

On aggregate, the law of large numbers means probability of individual level equals the actual outcomes. At any time t, within the support $(\bar{\phi}, \phi^{\max})$,

[11] The convenient specification of Haque and Kneller (2015) contradicts the model property of Lui (1986), which implies easier concealment when corruption becomes more prevalent. It also relies on the fact that the total number of public officials (N_t^{SG}) is constant, is not suitable here due to the endogeneity of both N_t^{SG} and ε_t. ε_t is determined based on the distribution of ϕ here, and in an economy where N_t^{SG} is expanding, the concealment cost may not be increasing with the N_t^{SG}.

we know that the number of corrupt officials equals $N_t^{SG} \int_{\phi_t^*}^{\phi^{\max}} f(\phi)d\phi$. The share of corrupted officials (as percentage of total public officials), ε_t, can therefore be computed as:

$$\varepsilon_t = \frac{\phi^{\max} - \phi_t^*}{\phi^{\max} - \bar{\phi}}, \tag{31}$$

where ϕ_t^* and $\bar{\phi}$ are as defined.

Compared to Haque and Kneller (2015), the share of corrupt public officials, ε_t, in this model is determined by the varying distribution of cost/profiteering opportunity by inflating expenditure. However, for the non-corrupt group, $1-\varepsilon_t$, the aggregate outcome is different from if there is no corruption. Specifically, the average claim made by non-corrupt public officials would equal $(1+\phi_t^*)/2$, instead of $\bar{\phi}$ (if there is no corruption). On aggregate, the actual quality of public capital goods procured is therefore expressed as

$$\begin{aligned} G_t^K &= (1-\varepsilon_t)N_t^{SG}\frac{g_t}{N_t^{SG}} + \varepsilon_t N_t^{SG}\Upsilon\frac{g_t}{N_t^{SG}} \\ &= [1-\varepsilon_t(1-\Upsilon)]g_t, \end{aligned} \tag{32}$$

while the total claims filed by the public officials add up to

$$\begin{aligned} G_t^I &= (1-\varepsilon_t)N_t^{SG}\frac{(1+\phi_t^*)}{2}\frac{g_t}{N_t^{SG}} + \varepsilon_t N_t^{SG}\frac{(\phi_t^* + \phi^{\max})}{2}\frac{g_t}{N_t^{SG}} \\ &= \{(1-\varepsilon_t)[(0.5)(1+\phi_t^*)] + \varepsilon_t[(0.5)(\phi_t^* + \phi^{\max})]\}g_t. \end{aligned} \tag{33}$$

2.6 Public Finance

In terms of the fiscal budget, the government is assumed to maintain a balanced budget at all time and cannot issue bonds to borrow. To finance its general outlays, the government levies a tax on non-public sector workers' wages at the rate τ, plus the salaries confiscated from apprehended corrupt officials. These outlays consist of the public emoluments, G_t^G, the funds allocated for public invesment (public capital goods purchase in this context), G_t^I, another funds allocated to provide minimum income in the form of social security payment/unemployment benefits to those unemployed in the economy, G_t^S, and spending on other items, G_t^O, assuming to be non-directly productive. It imposes no fees for its services.

The government's general budget is given by

$$G_t^G+G_t^I+G_t^S+G_t^O = \tau\{w_t^U N_t^{UY}+N_t^{SY}[(1-\varrho)w_t^S-tc_t]\}+(1-p)\varepsilon_t(1-\varrho)w_t^S N_t^{SG}, \tag{34}$$

where

$$G_t^G = (1-\varrho)w_t^S N_t^{SG}. \tag{35}$$

Shares of spending are constant fractions of government revenues:

$$G_t^i = \upsilon_i\{\tau\{w_t^U N_t^{UY}+N_t^{SY}[(1-\varrho)w_t^S-tc_t]\}+(1-p)\varepsilon_t(1-\varrho)w_t^S N_t^{SG}\}, \quad i=G,I,S,O \tag{36}$$

where $\upsilon_i \in (0,1)$. Combining (34) and (36) therefore yields

$$\upsilon_I+\upsilon_G+\upsilon_S+\upsilon_O = 1. \tag{37}$$

The tax-free nature of public officials' wage income means skilled workers will always prefer to work as government officials, though the total number employed at any period t, N_t^{SG}, is largely determined by the share of government revenues allocated to expenditure on emoluments. As seen in Appendix, equating (35) and (36) for G_t^G, we can derive an expression for the share of public officials in the economy, $\theta_t^{SG} = N_t^{SG}/\bar{N}$, as:

$$\theta_t^{SG} = \frac{N_t^{SG}}{\bar{N}} = \frac{\upsilon_G\tau\left\{\frac{\beta^U}{\Phi_t}+\left(1-\frac{\mu(1-\tau)}{[0.5(1+a_t^C)]^\chi}\frac{\theta_t^{SY}}{\theta_t^S}\right)\right\}\theta_t^{SY}}{\left\{[1-\upsilon_G(1-p)\varepsilon_t]+\upsilon_G\tau\frac{\mu}{[0.5(1+a_t^C)]^\chi}\frac{\theta_t^{SY}}{\theta_t^S}\right\}}, \tag{38}$$

where again, $\Phi_t = [(k_t^G)^{\varsigma_1^m}(1-\eta)\gamma]$, and θ_t^h, $h=U,S,UY,SY,SG$ denote the proportion of individuals of the respective category h in the adult population $\bar{N}$.

In terms of public investment, the government's allocation, G_t^I is based on the total claims made by public officials, not the actual quality. As such, even with assumed full depreciation, the evolution of public capital stock, $K^G_{t+1} = G^K_t$, but $K^G_{t+1} \neq G^I_t$, with the difference being the public funds embezzled by the corrupt officials. The evolution of public capital is therefore characterised by

$$\begin{aligned} K^G_{t+1} &= G^K_t \\ &= [1-\varepsilon_t(1-\Upsilon)]g_t \\ &= [1-\varepsilon_t(1-\Upsilon)]\psi Y_t. \end{aligned} \tag{39}$$

Let φ_t denotes a variable measuring the efficiency of public investment (a measure often modelled as exogenous, time-invariant parameter in standard growth models with public investment (see Agénor(2012))). As shown in the Appendix, we can compute φ_t by dividing (34) with (36), which yields

$$\varphi_t = \frac{G^K_t}{G^I_t} = \frac{[1-\varepsilon_t(1-\Upsilon)]\psi}{\begin{array}{c}\{\upsilon_I[\tau\beta^U + \tau\Phi_t(1-\varrho)(1-\frac{\mu}{[0.5(1+a^C_t)]^\chi}(\zeta^{SY}_t(1-\tau)+\zeta^{SG}_t)) \\ +(1-p)(1-\varrho)\Phi_t\varepsilon_t\frac{\theta^{SG}_t}{\theta^{SY}_t}]\}\end{array}}\frac{Y_t}{K^P_t}. \tag{40}$$

In terms of the unemployment insurance/social security fund, the flows' accounting can be expressed as

$$b_t[\theta^{UL}_t+(1-\varrho)\theta^{SL}_t]\bar{N} = \upsilon_S\{\tau\{w^U_t N^{UY}_t + N^{SY}_t[(1-\varrho)w^S_t - tc_t]\}+(1-p)\varepsilon_t(1-\varrho)w^S_t N^{SG}_t\},$$

which as shown in the Appendix, allows us to derive an expression for the benefit indexation variable, κ_t:

$$\kappa_t = \frac{\left\{\upsilon_S[\tau\beta^U + \tau\Phi_t(1-\varrho)(1-\frac{\mu}{[0.5(1+a^C_t)]^\chi}(\zeta^{SY}_t(1-\tau)+\zeta^{SG}_t)) + (1-p)(1-\varrho)\Phi_t\varepsilon_t\frac{\theta^{SG}_t}{\theta^{SY}_t}]\right\}}{\theta^{UL}_t + (1-\varrho)\theta^{SL}_t}. \tag{41}$$

2.7 Labour Market Identities and Savings-Investment Balance

To close the model, the equilibrium condition of the market for unskilled labour (and the relevant shares in terms of ratios) is given by

$$N_t^U = N_t^{UL} + N_t^{UY}, \quad \text{and} \quad \theta_t^U = \theta_t^{UL} + \theta_t^{UY}, \tag{42}$$

where $\theta_t^U = N_t^U/\bar{N}$, which from (8) equals to a_t^C. Thus, the probability of employment for an unskilled individual, ζ_t^{UY}, and the probability of an unskilled individual becoming unemployed, ζ_t^{UL}, are given respectively by

$$\zeta_t^{UY} = \frac{N_t^{UY}}{N_t^U} = \frac{\theta_t^{UY}}{\theta_t^U}, \text{ and } \zeta_t^{UL} = 1 - \zeta_t^{UY} = \frac{N_t^{UL}}{N_t^U} = \frac{\theta_t^{UL}}{\theta_t^U}. \tag{43}$$

The equilibrium condition of the market for (effective) skilled labour is given by

$$N_t^S = N_t^{SY} + N_t^{SG} + N_t^{SL}, \quad \text{and } \theta_t^S = \theta_t^{SY} + \theta_t^{SG} + \theta_t^{SL}. \tag{44}$$

The employment and unemployment probabilities for skilled workers are given by

$$\begin{aligned} \zeta_t^{SY} &= \frac{N_t^{SY}}{N_t^S} = \frac{\theta_t^{SY}}{\theta_t^S}, \quad \zeta_t^{SG} = \frac{N_t^{SG}}{N_t^S} = \frac{\theta_t^{SG}}{\theta_t^S}, \\ \text{and } \zeta_t^{SL} &= 1 - \zeta_t^{SY} - \zeta_t^{SG} = \frac{N_t^{SL}}{N_t^S} = \frac{\theta_t^{SL}}{\theta_t^S}. \end{aligned} \tag{45}$$

For the saving-investment balance, assuming full depreciation, the saving-investment balance requires private capital in $t+1$ to be equal to savings in period t by all individuals born in $t-1$:[12]

$$\begin{aligned} K_{t+1}^P &= (s_t^{U,Y} N_t^{UY} + s_t^{U,L} N_t^{UL}) + [s_t^{SY} N_t^{SY} + +s_t^{S,L} N_t^{SL} \\ &+ s_t^{SG,Nc}(1-\varepsilon_t) N_t^{SG} + s_t^{SG,c,p} \varepsilon_t N_t^{SG,c,p}]. \end{aligned} \tag{46}$$

[12] For convenience, we assume that the corrupt officials (that are not caught) are able to invest the embezzled funds and earn standard market interest rate. Alternative, we could have specified the model such that the embezzled funds can be invested in the black market and earns a fraction of the market interest rate. This does not make a significant difference to the results.

3 Dynamic System and Balanced Growth Equilibrium

In this economy, an *imperfect equilibrium with corruption and unemployment* is a sequence of consumption and saving allocations $\{c_{t|t}^{h,j}, c_{t|t+1}^{h,j}, s_t^{h,j}\}_{t=0}^{\infty}$, for $h = U, SY, SG$, $j = E, L$, prices of production inputs $\{w_t^U, w_t^S, r_{t+1}\}_{t=0}^{\infty}$, existing blueprint varieties $\{M_t\}_{t=0}^{\infty}$, private capital $\{K_t^P\}_{t=0}^{\infty}$, public capital $\{K_t^G\}_{t=0}^{\infty}$, such that, given initial stocks M_0, K_0^P, $K_0^G > 0$,

a) all individuals, skilled or unskilled, employed or unemployed, publicly or privately employed, maximise utility by choosing consumption subject to their intertemporal budget constraint, taking factor prices, the tax rate, and the unemployment benefit as given;

b) the public officials maximise utility by choosing the cost to report (hence to corrupt or not to corrupt), taking the overall distribution of the purchase cost, ϕ, the probability of being detected, the quality of the final goods, and the public funds allocated for public investment as given;

c) firms in the final good sector maximise profits by choosing labour, private capital, and intermediate inputs, taking factor prices as given;

d) intermediate producers set prices so as to maximise profits, given the perceived aggregate demand curve for their product;

e) design firms maximise profits by choosing skilled labour, taking wages, patent prices, and public-private capital ratio as given;

f) each equilibrium design fee extracts all profits made by the corresponding intermediate producer; and

g) the trade union sets wages so as to maximise its utility, subject to the demand for labour by firms in the final good sector;

h) the final good market clears;

i) unemployment of both categories of workers prevails; and

j) non-zero share of corrupt officials prevails among the public officials.

A *balanced growth equilibrium* is an equilibrium with corruption and unemployment in which

a) $\{c_{t|t}^{h,j}, c_{t|t+1}^{h,j}, s_t^{h,j}\}_{t=0}^{\infty}$, for $h = U, SY, SG$, $j = E, L$, and K_t^P, K_t^G, Y_t, w_t^U, w_t^S, b_t, grow at the constant, endogenous rate $1 + \gamma$, implying that the blueprint-private capital ratio and the public-private capital ratio is constant;

b) the rate of return on capital, $1 + r_{t+1}$, is constant;

c) the threshold level of individuals who choose to remain unskilled, a_t^C, is constant;

d) the threshold level of cost above which public officials opt to corrupt, ϕ_t^*, is constant;

e) the fractions of the skilled and unskilled labour force employed in manufacturing, θ_t^{UY} and θ_t^{SY}, and the fraction of officials employed in the public sector, θ_t^{SG}, are constant;

f) the proportion of the public officials who are corrupt, ε_t, is constant;

g) the benefit indexation variable (as a ratio of income per capita), κ_t, is constant;

h) the price of intermediate goods P_t and the fee Q_t, is constant;

i) skilled and unskilled unemployment rates, θ_t^{UL} and θ_t^{SL}, are constant; and

j) employment and unemployment probabilities, ζ_t^{UY}, ζ_t^{SY}, ζ_t^{SG}, and ζ_t^{UL}, ζ_t^{SL} are constant.

In terms of properties of the equilibrium, as shown in the Apppendix, the dynamics of the model are mainly driven by the two difference equations of K_t^G/K_t^P and M_t/K_t^P, as well as core static equations in terms of the final good-private capital ratio, Y_t/K_t^P, the threshold level of ability (or equivalently the share of unskilled workers), a_t^C, the shares of skilled workers in final good production and public sector, θ_t^{SY} and θ_t^{SG}, the proportion of public officials that are corrupt, ε_t, the threshold level of procurement cost, ϕ_t^*, the share of unskilled workers in final good production, θ_t^{UY}, the shares of skilled and unskilled workers in unemployment, θ_t^{SL} and θ_t^{UL}, and the benefit indexation ratio, κ_t . For the case in which $\psi_t = K_t^G/Y_t$ is endogenous and varies over time, the relevant ψ's in the derived equations are replaced by $K_t^G/K_t^P/\ Y_t/K_t^P$, and a relatively more complicated system is solved separately.

A key step in deriving the equilibrium growth rate is to establish the restrictions needed on the congestion parameters in (10). Let $m_t = M_t/K_t^P$, this involves setting $\beta^U = \zeta\iota$ and $\alpha + \gamma/\eta + \iota + \omega = 1$. Rearranging terms, we can then yield an expression for Y_t as a linear function of K_t^P:

$$Y_t = \frac{(k_t^G)^{\omega/(1-\gamma)}(\gamma\eta)^{\gamma/(1-\gamma)}}{[(\theta_t^{UY})^{\beta^U}]^{-1/(1-\gamma)}} \left\{{m_t}^{(1-\eta)/\eta}\right\}^{\gamma/(1-\gamma)} K_t^P. \tag{47}$$

To determine the growth rate of final output, $1 + \gamma_t$, note that the growth rate of final output equals the growth rate of physical capital. As shown in the Appendix, this means we can calculate growth rate in each period t as

$$1+\gamma_t = \frac{K_{t+1}^P}{K_t^P} = \sigma \frac{Y_t}{K_t^P} \left\{ \begin{array}{c} (1-\tau)\beta^U + \kappa\theta_t^{UL} + (1-\tau)\left[1 - \frac{\mu[\zeta_t^{SY}(1-\tau)+\zeta_t^{SG}]}{[0.5(1+\theta_t^U)]^\chi}\right]\Phi_t(1-\varrho) \\ +(1-\varrho)\left[\kappa\theta_t^{SL} - \frac{\mu[\zeta_t^{SY}(1-\tau)+\zeta_t^{SG}]}{[0.5(1+\theta_t^U)]^\chi}\Phi_t\frac{\theta_t^{SL}}{\theta_t^{SY}}\right] \\ +(1-\varepsilon_t)\Phi_t(1-\varrho)\frac{\theta_t^{SG}}{\theta_t^{SY}}\left[1 - \frac{\mu[\zeta_t^{SY}(1-\tau)+\zeta_t^{SG}]}{[0.5(1+\theta_t^U)]^\chi}\right] \\ +p\varepsilon_t\Phi_t(1-\varrho)\frac{\theta_t^{SG}}{\theta_t^{SY}}\left[1 - \frac{\mu[\zeta_t^{SY}(1-\tau)+\zeta_t^{SG}]}{[0.5(1+\theta_t^U)]^\chi}\right] + p\varepsilon_t\psi\left[1 - \left(\frac{\theta_t^{SL}}{\theta_t^{UL}}\right)^\delta\right]\left[\frac{\phi_t^*-1}{2}\right] \end{array} \right\}. \tag{48}$$

Given the complexity of the system, both the solutions and the stability of the system cannot be studied analytically. However, it is established numerically based on a parameterised model by solving for an initial balanced growth equilibrium that satisfies the properties defined earlier and verifying that following a shock, the system converges to a new equilibrium.

4 Model Parameterisation

To examine the model properties and to study the general equilibrium effects of policy parameters, we parameterise the system based on the federal republic of Nigeria, a lower-middle income, Sub-Saharan African economy historically known for having widespread corruption (Bakare, 2011) and structural unemployment (Kester et al, 2016). The current President Buhari's administration identified corruption and unemployment as main policy priorities, against the bakdrop of continuing poor public service delivery and sluggish growth. The parameterisations are based primarily on official statistics obtained from the various publications of the National Bureau of Statistics, Nigeria ('NBS Nigeria'). Unless specified otherwise, all statistics are based on the average during the 2011-15 period.

On the *household* sector, the annual discount rate is set at 0.04. With a 25 years OLG structure, this gives an intergenerational discount rate of 0.375. The household savings rate, σ, is estimated using the household survey data. Specifically, based on average monthly income of NGN50,000 minus off consumption expenditure, the household savings rate is estimated to be 9.3 percent. For the time spent in tertiary education, based on a standard 3.5 years spent in the university, $\varrho = 3.5/25 = 0.140$ is obtained. In terms of efficiency of training, the parameter χ is set at 0.7, which is in between the 0.9 set by Agénor and Lim (2017) for high-income economy and the 0.5 set by Agénor and Alpaslan (2014) for the poorest low-income economy. In the absence of training cost data, the parameterised value for the skills acquisition cost (proportion to skilled wages), μ, is solved for using the equation for θ_t^U, written below for convenience:

$$\theta^U = \mu^{1/\chi} \left\{ 1 - (1-\varrho)^{-1} \frac{[\zeta^{UY}(1-\tau) + \zeta^{UL}\kappa - (1-\varrho)\zeta^{SL}\kappa]}{\zeta^{SY}(1-\tau) + \zeta^{SG}} \left(\frac{\theta^{SY}}{[(k^G)^{\varsigma_1^m}(1-\eta)\gamma]} \right) \right\}^{-1/\chi}.$$

To solve for μ, we still need the tax rate (τ), information from the intermediate goods and design sector (ς_1^m, η, γ), the initial values for k^G, and the relevant labour shares and probabilities. The tax rate on wages, $\tau = 0.058$, is estimated by dividing the total tax revenue as percentage of GDP (obtained from World Bank World Development Indicators) by the labour share of the GDP in Nigeria. The latter is calculated based on the compensation of employees amount in the national income statistics, yielding 0.28. This also provides the value for the elasticity of final good production to employed labour ratio in the final good sector, $\beta = 0.28$. For the rest of the production parameters in the *final good* sector, the elasticity parameter with respect to private capital, α, is set at 0.35, following Agénor and Lim (2017) and within the standard range for developing economies. Constant return-to-scale assumption for the production function means $\gamma = 1 - \alpha - \beta = 0.37$. Lastly, for the elasticity of production with respect to the public-private capital ratio, ω is set at 0.173, in line with the meta-analysis of Bom and Ligthart (2014).

In the *intermediate goods and design* sector, the substitution parameter, η, is set at 0.39, which is consistent with Lim (2015) and the non-competitive scenario examined in Sequeira (2011). For the elasticity with respect to public capital, ς_1^m, we use the lower-range estimate of Agénor and Neanidis (2015), $\varsigma_1^m = 0.10$, which is the same as the value used in Agénor and Alpaslan (2014).

Before moving on to the public sector and the unions, first, we sort out the initial steady-state values for the labour variables, especially those that are required in the calculation of μ. The share of unskilled workers in the population, θ^U, is set equal to 0.847, which is calculated by subtracting the share of workers with post-secondary qualification in Nigeria as at end-2015. This gives $\theta^S = 0.141$. Using the same publication from the NBS Nigeria, the skilled, θ^{SL}, and unskilled unemployment rate, θ^{UL}, are calculated using the raw unemployed numbers as at end-2015, which gives $\theta^{SL} = 0.036$ and $\theta^{UL} = 0.106$, with the weighted average gives the headline unemployment rate of 0.104. The probability of a skilled worker getting unemployed, $\zeta_t^{SL} = 0.255$, and the probability of an unskilled worker getting unemployed, $\zeta^{UL} = 0.125$, are easily derived. After that, the share of unskilled workers hired in the private sector, θ^{UY}, and the corresponding probability, ζ^{UY}, can be calculated, where $\theta^{UY} = \theta^U - \theta^{UL} = 0.741$, and $\zeta^{UY} = \theta^{UY}/\theta^U = 0.875$. For the share of public officials, first we know that the number of skilled civil servants at grade GL12-GL17 of Nigerian public service as at end-2015 equals $141,515$. Dividing this by the total labour force as reported by the World Bank, 59.1 million, gives $\theta^{SG} = 0.0024$, and the corresponding probability, $\zeta^{SG} = 0.017$. The share of skilled labour employed in the private sector, $\theta^{SY} = 0.103$, and the corresponding probability, $\zeta^{SY} = \theta^{SY}/\theta^S = 0.728$, can then be calculated. Lastly, in the absence of public capital stock data, the public-private capital ratio, k^G, is set at 0.16, which corresponds to the average estimate for the non-high income, Sub-Saharan African economies used in Agénor and Alpaslan (2014). Given all these initial values, we can then calculate the skills acquisition cost, μ, which equals to 0.229.

In terms of the union bargaining parameters, ξ^U and ξ^S, to our knowledge, there is no econometric estimation for the union wage premium in Nigeria. As such, we rely on the estimate of Barnerjee et al. (2008) for South Africa, which documented a wage mark-up of 1.23 times. Using (23), $\xi^U = \xi^S = 0.158$ are estimated. The same problem arises with the wage elasticities with respect to unemployment level, $\varkappa^U$ and $\varkappa^S$. Using the average elasticity estimated by Kingdon and Knight (2006), again for South Africa, we set both $\varkappa^U$ and $\varkappa^S$ to equal 0.108.

For the remaining variables and parameters in the *public sector*, using personnel cost data in the *Public Finance Statistics* published by the NBS Nigeria, $\upsilon_G = 0.337$ is estimated. The share of spending on public infrastructure, υ_I, is obtained by dividing the public infrastructure investment as a percentage of GDP as at end-2015 with the total government expenditure as a percentage of GDP, which gives $\upsilon_I = 0.187$. The share of total social spending/benefits as a percentage of government expenditure, υ_S, cannot be ascertained directly from the public finance statistics, and therefore needs to be solved for using (41). This requires us to first estimate the initial steady-state value of κ. In general, Nigeria is a federation of states where both the minium wage and unemployment benefits are not uniformly binding across all states. However, as at end-2015, the minimum wage stands at NGN18,000 (approximately USD55). Dividing this over an average income per capita of USD2,671, we set $\kappa = 0.02$. To estimate for the initial share of corrupt officials, ε (which is always contentious to do so), we use a combination of the numbers (proportion of civil servants declaring their assets) published in the *Social Statistics Report 2016* and the '*percentage of firms making informal payments to public officials in Nigeria*' number contained in the World Development Indicators. The share of civil servants not declaring their assets equals 0.425, while the latter is about 0.79. Assuming that this is representative of the share of those non-declared officers who are corrupt, we estimate $\varepsilon = 0.336$. In terms of the probability of being detected, $1 - p$, in order to be consistent with the Buhari administration's renewed commitments in tackling corruption (as evidenced by the recent spike in convicted offence), we set $1 - p = 0.8$, or equivalently, $p = 0.2$. This therefore indicates a relatively robust monitoring technology, despite the high corruption rate, and rules out potentially the use of a foolproof exogenous p shock as a straightforward policy measure to tackle corruption in the next section. Given all the parameterised initial values and parameters, υ_S is estimated using (41), which gives $\upsilon_S = 0.125$. Lastly, we still need to estimate $\phi^{\max}$ and then determine the initial steady-state value of ϕ^*. Given all the calibrated parameters and initial values, we first calculate $\phi^* - \bar{\phi}$ using (30), which gives 0.098. Solving this simultaneously with (31), we obtain $\phi^* = 1.246$, $\phi^{\max} = 1.296$, and subsequently, $\bar{\phi} = 1.148$.

The final output-private capital ratio, Y/K^P, is estimated using GDP and private capital stock series obtained from the Penn World Table 9, which gives $Y/K^P = 0.524$ for Nigeria. This, couple with the initial steady-state value of public-private capital ratio, $k^G = 0.16$, allows for the calculation of ψ, which equals 0.305. Following Agenor and Lim (2017), the blueprint-private capital stock ratio, m, is normalised to 0.1, largely for convenience and the fact that this initial ratio is immaterial to the results. The public investment efficiency ratio, φ_t, is set equal to 0.285, which is based on the 1.14 index score (out of 4.0) estimated by Dabla-Norris et al. (2012). Finally, the annual growth rates for final output and private capital in the initial steady state are equal to 4.7 percent, which corresponds to the average real GDP growth rate of Nigeria during the period 2011-15. The calibrated parameters and the initial steady-state values are summarised in Table 1 and 2 respectively.

5 Policy Experiments

In line with the recent policy development in Nigeria, we start off by considering two policy scenarios: (i) public sector downsizing (a cut in υ_G), which is a measure widely documented to be undertaken by the Obasanjo government in the late 1990s (Kester et al., 2016); and (ii) an attempt raise in minimum income by increasing the endogenous social security/benefit rate, κ_t, which can be achieved by increasing the share of spending in social security/benefits in the budget, υ_S. The latter is consistent with President Buhari's *Social Intervention Scheme*, which when simulated together with a training cost cut, μ, allows for potentially achieving the simultaneous goal of job creation/unemployment reduction. In addition, we also consider a scenario where there is a reduction in the unskilled workers' union mark-up, which is usually a popular policy means in the labour market reform literature to be used in increasing the absoprtion of unskilled workers into the workforce.

After that, we simulate a conventional public infrastructure-push policy scenario by increasing υ_I. To preview, readers experienced in economic dynamics would notice from the Appendix that, in a corruption model with leakages such as this (where the actual quality does not depend on 'on-paper' reported expenditure), the parameter υ_I is policy-neutral and does not appear anywhere in the difference equation system, saved for the public investment efficiency index, φ_t. To overcome this characteristic of the benchmark solution, we examine a policy scenario with endogenous threshold. Specifically, assuming a policy scenario where after a period of ambitious anti-corruption reform reducing the corruption rate, ε_t, to below a certain threshold level, the dynamics of the system would then change, in which equation (39) is replaced by the actual on-paper measure of (36). This may be interpreted as the government successfully reducing the corruption rate to a negligible level, hence closing the reporting gap between public finance and actual public procurement.

As mentioned, for all the experiments, in addition to the benchmark case, we also consider sensitivity analysis cases where there is (i) endogenous ψ_t; (ii) evolving probability p over time, by virtue of the one-to-one relationship with monitoring intensity[13]; and (iii) a linear specification for the concealment cost (elasticity parameter, $\delta = 1.0$), which also implies a stronger relationship between the unemployment rates and the concealment cost). All the policy shocks considered are permanent and their impact is measured in terms of a few key vaßriables—the public investment efficiency index, the corruption rate, the unemployment rates, the size of the public sector employment, and the growth rate of the final output. Unless specified otherwise, all policy experimented involves a 10 percent increase/decrease. All the simulation results (impact and steady-state effects) are summarised in Tables 3-6, with the transitional dynamics associated with selected policy experiments (primarily to save space) presented in Figures 1-4.[14]

5.1 Public Sector Downsizing

First, consider a 10 percent cut in the share of spending on public emoluments, υ_G, where the saved amount gets reallocated to other non-directly productive expenditure component, υ_O. Both the impact and steady-state effects are presented in Table 3, with the transitional dynamics of key variables illustrated

[13] A common specification used in the development economics literature to model gradual evolution involves assuming p to evolve according to $p_t = (p_{t-1})^{\mu_P}(p_m \frac{\tilde{N}}{\varepsilon_t N_t^{SG}})^{1-\mu_P}$, where μ_P, set equal to 0.8 here, essentially means a high persistence for p. However, in consistent with studies such as Haque and Kneller (2015), we assume that it gets easier for the government to detect corruption the larger the share of corrupt officials becomes in the population.

[14] Similar to Agénor and Alpaslan (2014), Agénor and Lim (2017), and other OLG models examining transitional dynamics in the literature, there is a distinction between generational periods (T) and simulated period (t). In principle, T corresponds to 25 years in the OLG structure, as reflected in the discount factor and the assumption of full depreciation of physical capital. However, all of the other parameters and variables either do not have a time dimension or are calibrated on the basis of average annual data. For the numerical experiments, the intended length of a unit of time interval is therefore $t = 1/25$, or best understood as one year.

in Figure 1. From (38), we see that a υ_G cut has a direct downward shift effect on the effective share of public officials, θ_t^{SG}, in the economy. Given initial fixed amount of effective skilled labour, θ_t^S, and those employed in the private sector, θ_t^{SY}, this means there is a corresponding increase in skilled unemployment, θ_t^{SL}, on impact. On the surface, by virtue of the specification of (29), the intended aim of such a policy intervention may be to provide an *uemployment-as-disciplinary*, corruption-prevention incentive for the public officials, at the cost of a slight increase in skilled unemployment. However, in this model where public spending on emoluments have productive implications (despite the possibility of corruption), and there are richer feedback mechanisms, the general equilibrium effects of public sector workforce downsizing actually leads to more corruption in the economy. First, given that the non-tax deductible skilled wage of a public official represents the best job possibility for a skilled worker, the fall in the probability of a skilled worker getting employed as a public official means a decline in the expected skilled wages. This results in a disincentive for skills acquisition in the economy, which is reflected in the increase (decrease) in the share of unskilled (skilled) workers in the economy. This larger unskilled workforce then has a proportionate impact on the unskilled unemployment rate.

At the same time, in the public sector, less number of public officials means, given fixed units of public capital goods demanded in each period, g_t, each remaining public official is now in-charged of procuring more. This gives more potential room for the inflating of procurement cost, or mathematically, translates to a larger gap between the incentive for corruption threshold, ϕ_t^*, and the maximum-reportable $\phi^{\max}$, as seen in (30). Indeed, this direct effect dominates the effect of the unemployment ratio has on the concealment cost. For any given number of public officials that is remaining employed by the public sector, the share of those corrupt officials therefore rises. There is then a wider gap between the actual quality of public capital and the reported investment expenses, hence translating to a decline in public investment efficiency.

Over the long-run, for a given g_t/N_t^{SG} unit of procurement responsibility, smaller N_t^{SG} translates to an overall smaller g_t, which implies a smaller public-to-private capital ratio in the economy. In the steady state, this is slightly detrimental to growth—a decline in final output growth rate in the order of -0.15 percentage points. In terms of the labour market, in the steady state, the level effect associated with the overall drop in the total pool of skilled workers eventually overwrite the positive impact of skilled unemployment rate, resulting in a steady-state net decline in θ_t^{SL} in the order of -0.03 percentage points. The overall impact on the headline unemployment rate is mildly positive, due to a larger steady-state increase in the unskilled unemployment rate. In terms of the public sector, in the steady state, the corruption rate, ε_t, ends up 7 percentage points higher, despite a smaller share of public officials in the economy. This, coupled with the -0.6 percentage points change in public investment efficiency and negative output growth rate, means a vanilla public sector downsizing strategy can be detrimental to such an economy. Indeed, it can be argued that the steady-state policy effects of an increase in the headline unemployment rate, a decrease in public investment efficiency, an increase in the economywide corruption rate, and a slightly negative growth effects are largely consistent with the economic performance observed during the infamous public sector downsizing era of the Obasanjo government, as described by Kester et al. (2016). Both Table 3 and Figure 1 also illustrate the policy effects under the other three sensitivity scenarios, which present largely similar policy dynamics to the benchmark case (in the case with endogenous ψ_t, the generated solutions are much more unstable, though the overall transitional paths remain consistent).

In Table 1, we also consider an alternative scenario where the saved expenses from a υ_G cut is reallocated instead to social spending, υ_S. Overall, we see that the effects are not much different from those observed in the previous scenario, only that the disincentive effect on skills acquisition becomes smaller (the cost associated with becoming unemployed after acquiring skills [arisen from the retrenching public officials] is marginally smaller, given that the level of unemployment benefits received for the skilled unemployed is higher in this scenario), with skills unemployment rate remains positive even in the long-run. The steady-state corruption rate is also slightly lower, though the negative growth effect becomes relatively larger due to overall lower level of production in the economy. This also suggests that the general equilibrium effects associated with a υ_G cut is likely to dominate those associated with the υ_S rise, which is examined next.

5.2 Raising Minimum Income and Training

President Buhari's Social Intervention Scheme (SIS) comes with the intention of creating more jobs, while simultaneously raising the minimum income of the population. In the context of this model, we consider policies of similar nature, starting with a plain 10 percent increase in the share of social security/benefit spending, υ_S, financed by a reallocation from other non-directly productive spending, υ_O. The results are illustrated in both Table 4 and Figure 2. Compared to the previous scenario where such a scheme is financed by a cut in emoluments, the overall policy effects are much improved.

In the context of the overall system, as seen in (41), an increase in υ_S, ceteris paribus, leads to a larger indexation rate, κ_t. This means the minimal income in the economy, b_t, for a given level of per capita income, increases. This results in the increase in both the expected skilled wage and the expected unskilled wage, though the effect on the former tends to be slightly larger (by virtue of the level, $w_t^S > w_t^U$). This therefore creates a net positive skills acquisition incentive (level effect), resulting in the overall expansion of skilled workforce in the economy. Nevertheless, in terms of reallocation effect, this policy predictably, does badly in combatting unemployment, as both the skilled and unemployment rates go up—the former increases 0.3 percentage points in the steady state, while the latter by 0.8 percentage points. The level of employment in the private sector for both types of workers is lower, resulting in lower production and a negative impact effect on real output growth, in the order of -0.1 percentage points in the steady state.

Nevertheless, instead of labelling such a policy as ineffective in typical classical economic interpretation, this policy does have its merits in an economy with corruption such as this. Overall, the net effect or the change in unemployment ratio, $\theta_t^{SL}/\theta_t^{UL}$, is positive (by virtue of the initial level of skilled unemployment being lower). From (29), this means the impact on concealment cost is higher, as the *uemployment-as-disciplinary*, corruption-prevention incentive is in action here. For any given cost associated with public procurement, the required mark-up (inflated cost) for any official to corrupt becomes higher. Specifically, the incentive for corruption threshold, ϕ_t^*, becomes larger, which in turns resulting in a smaller gap between ϕ_t^* and $\phi^{\max}$. In the steady state, the share of corrupt officials therefore falls by 0.6 percentage points.

Indeed, the conventional argument for the use of minimum wage and unemployment benefit provision tend to focus on their potential effects in incentivising the poor to accumulate human capital. In other words, if such a policy is associated with a simultaneous reduction in the skills acquisition cost in the economy, then the economic implications are good. A crude experiment to examine this involves simulating an increase in υ_S and μ each by 10 percent, financed by a 20 percent cut in υ_O, as also shown in Table 4. The skills expansion effect is predictable larger, which is associated with a smaller deviation in unskilled unemployment rate (by implications, the overall headline unemployment rate), though still positive, and more importantly, a positive steady-state effect on real output growth rate. While this scenario does result in a by-product of a slightly larger skilled unemployment rate, this is warranted as, along with higher expected skills wage premium, it provides a stronger corruption-prevention incentive, which in steady state, translates to a -8 percentage point change in the share of corrupt officials. In others words, the share of corrupt officials declines from the initial 33.6 percent of total public officials to 25.6 percent. This decline in corruption, together with the positive growth effect associated with skills expansion, also leads to an improved public investment efficiency ratio by 0.4 percentage points.

5.3 Ambitious Social Reform Programme

As seen in the previous experiments, there is some merits in using a minimum income/wage strategy in addressing corruption in a developing economy. However, any ambitious social reform programme must necessarily also aim to reduce the headline total unemployment rate. In the model context, a policy that can achieve a reduction in unskilled unemployment rate is through union reform—one of the labour market institutions found by Bernal-Verdugo et al. (2012) to be effective in reducing unemployment for their non-OECD country sample. More specifically, consider a 10 percent reduction in the parameter ξ^U, which governs the mark-up over the target wage for the unskilled workers, as seen in (23)). In a non-technical context, within such a model where there is no explicit distinction between participation rate, this may be interpreted as a policy designed to bring more unskilled workers into the employed labour force.The same The results of this individual policy are summarised in Table 5, with the transitional dynamics presented in Figure 3. In all four cases analysed, the steady-state effect on unskilled unemployment rate is consistently negative. While the effects on growth and skilled unemployment rate are marginally lower and higher respectively, this individual policy provides another useful tool in tackling corruption while simultaneously reducing the headline unemployment rate.

Next, we consider an ambitious composite reform programme, which has overall policy elements that are consistent with the SIS in Nigeria. Specifically, we consider an increase in υ_S by 10 percent, a training cost cut, μ, by 20 percent, and a reduction in ξ^U by 20 percent (which translates to 1.17 times of mark-up), with both the impact and steady-state results also presented in Table 5. In the steady-state, we see that there is a robust increase in the effective share of skilled labour by 1.3 percentage points, a decline in headline unemployment rate in the order of -0.4 percentage points, and a positive growth effect of 0.25 percentage points. However, the absolute deviation of public investment efficiency index remains negative, and the skilled unemployment rate increases by 1.2 percentage points. With the policy tool of public infrastructure investment share, υ_I, being irrelevant in this dynamic system, there is no room for the use of a conventional infrastructure-push policy to address these two shortcomings. Nonetheless, in the benchmark case, the programme is very effective in reducing the public sector corruption rate in the economy, with the benchmark case registering a steady-state deviation of the order -25.9 percentage points, or equivalently, reducing corruption rate to only 7.6 percent of the total public officials in the economy. Indeed, at some point along the transition, corruption rate is reduced to an insignificant level, which paves the way for a subsequent examination of an endogenous threshold case in the following sub-section on public investment.

5.4 Public Investment in Infrastructure

As documented in Agénor (2012) and Agénor and Lim (2017), public investment in infrastructure, through its productivity-enhancing supply-side effects, can be a powerful tool in raising final output growth while addressing the persistent absoprtion/skilled unemployment issue associated with a skills expansion policy. However, in a corruption-based model such as this where there is a difference between actual quality and reported public investment expenses, a measure such as υ_I becomes impotent (as seen in Table 6). Nevertheless, a conceptually plausible composite reform strategy is to first push the corruption rate in the economy down to an insignificant level, after which the government will be able to wipe out corruption and close the quality-reporting gap associated with public investment. In such instance, υ_I can then become a viable policy tool in an economy free of corruption. Specifically, we introduce an endogenous threshold of (insignificant) corruption level, $\hat{\varepsilon} = 0.03$, after/below which then the dynamics are driven by a slightly modified system in which the numerator in the public-private capital ratio is replaced from (39) to the public finance definition of (36), $\phi_t^* = \phi^{\max}$, and corruption set at a constant value.

For all four cases studied (benchmark, plus the other three sensitivity analysis cases), we introduce this endogenous switching condition and examine again, the ambitious composite reform programme, plus an increase in υ_I also by 10 percent. The experiment results are summarised in Table 6, with transitional dynamics presented in Figure 4. Of the four cases we studied, only the benchmark model triggers the threshold condition where in period $t = 4$, the corruption rate drops past $\hat{\varepsilon} = 0.03$. As such, for the dynamics illustrated in Figure 4, save for the line labelled 'Benchmark (with switching)' and the graph for public investment efficiency, the other four represent exactly the same transitional dynamics that we would have observed for the composite programme examined earlier (given the irrelevance of υ_I prior to switching).

Comparing the benchmark case with and without switching, we see that the subsequent introduction of υ_I results in final output growth rate to end at +0.3 percentage points at end-steady state. There is a huge gain in public investment efficiency as a result of the regime change, and the increase in skilled unemployment rate has become much more manageable. Nonetheless, the policy effects on reducing unskilled and headline unemployment rate has become not as effective in such a hypothetical corruption-free model economy. These results provide interesting food-for-thought on whether social policies designed to reduce unemployment rate would work as well in a zero-corruption economy, especially given the existence of the dynamic tradeoff between skilled unemployment and corruption.

6 Concluding Remarks

This papers presents a dynamic OLG growth model with heterogeneous labour, endogenous unemployment and public sector corruption. The model does not separate public officials and private individuals into two distinct groups. Instead, taking up bureaucratic appointment as a public servants is modelled as an occupational choice, which then allows for the endogenous determination of all three variables of the proportion of public officials, the share of corrupt officials among them, and the public investment efficiency within a dynamic system. Parameterised for Nigeria, the dynamics of endogenous corruption and unemployment, as well as their policy tradeoff, are studied using simulated policy experiments, ranging from public sector downsizing, social intervention scheme, to an ambitious social reform programme preceding a push in public infrastructure investment.

The dynamic relationship between unemployment and corruption in this model depends critically on the specification of the concealment cost function. While sensitivity analysis results seem to suggest that functional specification does not significantly affect the results, the validity of the Shapiro-Stiglitz type of *uemployment-as-disciplinary* mechanism does play a significant role in shaping the unemployment-corruption nexus in this model. While there are empirical studies documenting this relationship, such as Bouzid (2016), the empirical validity remains limited. As such, for future studies, a rigorous empirical examination based on a more parsimonious version of this model is warranted. In terms of theoretical extension, the model can be extended to account for other forms of public sector corruption, notably those associated with tax collection. That will then enable more detailed examinations of the tax implications, which is a feature largely simplified in this model.

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Table 1
Parameter Values: Benchmark Case

Parameter	Description	Value
Households		
ρ	Intergenerational discount rate	0.375
σ	Household savings rate	0.093
χ	Training productivity parameter	0.7
μ	Skills acquisition cost	0.229
ϱ	Time allocated to university	0.140
Private sector production		
ω	FG elasticity wrt public-private capital ratio	0.173
β	FG elasticity wrt unskilled workers	0.28
α	FG elasticity wrt private capital	0.35
γ	FG elasticity wrt intermediate input	0.37
η	Substitution parameter, intermediate goods	0.39
ς_1^m	Blueprint elasticity wrt public services	0.100
Public sector		
τ	Tax rate on total wages	0.058
υ_I	Share of spending on infrastructure	0.187
υ_G	Share of spending on public emoluments	0.337
υ_S	Share of spending on social security/benefits	0.125
Υ	Sub-quality public capital good purchase	0.7
δ	Elasticity parameter, concealment cost	0.5
p	Probability of avoiding detection	0.8
$\phi^{\max}$	Upper bound, cost for inflated reporting	1.296
ψ	Ratio of capital goods demanded by government	0.305
Labour union		
ξ^U	Relative weight, unskilled workers	0.158
ξ^S	Relative weight, skilled workers	0.158
$\varkappa^U$	Elasticity wrt unemployment, unskilled wage	0.108
$\varkappa^S$	Elasticity wrt unemployment, skilled wage	0.108

Table 2
Initial Steady-State Values of Key Variables

Variable	Description	Value
θ^U	Share of unskilled workers in population	0.847
θ^S	Share of effective skilled workers in population	0.141
θ^{SG}	Share of (effective skilled) public officials	0.002
θ^{SY}	Share of effective skilled workers in private sector	0.103
θ^{SL}	Skilled unemployment rate	0.036
θ^{UY}	Share of unskilled workers in private sector	0.741
θ^{UL}	Unskilled unemployment rate	0.106
ζ^{SG}	Prob. of skilled workers employed in public sector	0.017
ζ^{SY}	Prob. of skilled workers employed in private sector	0.728
ζ^{SL}	Prob. of skilled workers getting unemployed	0.255
ζ^{UY}	Prob. of unskilled workers getting employed	0.875
ζ^{UL}	Prob. of unskilled workers getting unemployed	0.125
ε	Corruption rate	0.336
κ	Social security/benefit rate, to per capita income	0.020
k^G	Public-private capital ratio	0.160
Y/K^P	Final output-private capital ratio	0.524
m	Blueprint-private capital stock ratio	0.100
ϕ^*	Optimal threshold cost for inflated reporting	1.246
φ_t	Public investment efficiency	0.285

Table 3

Policy Experiment Results for (i) Public Sector Downsizing, and (ii) Public Sector Downsizing, but with reallocation to Social Security Spending

	Baseline	Absolute Deviations from Baseline							
		Benchmark		Endogenous ψ		Endogenous p		δ = 1.0	
Public Sector Downsizing:[a]		Impact	Steady-state	Impact	Steady-state	Impact	Steady-state	Impact	Steady-state
Share of unskilled workers	0.847	**0.0002**	**0.0019**	0.0002	0.0010	0.0002	0.0014	0.0002	0.0021
Effective share of skilled workers	0.141	**-0.0001**	**-0.0016**	-0.0001	-0.0008	-0.0001	-0.0012	-0.0002	-0.0018
Effective share of public officials	0.002	**-0.0002**	**-0.0002**	-0.0002	-0.0002	-0.0002	-0.0002	-0.0003	-0.0003
Skilled unemployment rate	0.036	**0.0001**	**-0.0003**	0.0001	-0.0002	0.0001	-0.0003	0.0000	-0.0005
Unskilled unemployment rate	0.106	**0.0002**	**0.0007**	0.0002	0.0003	0.0002	0.0004	0.0001	0.0003
Headline unemployment rate	0.104	**0.0002**	**0.0007**	0.0002	0.0003	0.0002	0.0004	0.0001	0.0003
Share of corrupt officials	0.336	**0.0619**	**0.0695**	0.0619	0.0435	0.0550	0.0479	0.0453	0.0496
Social Security/Benefit rate	0.020	**0.0000**	**0.0000**	0.0000	0.0000	0.0000	0.0000	-0.0001	0.0000
Growth rate of final output	0.047	**0.0000**	**-0.0015**	0.0000	-0.0009	0.0000	-0.0010	0.0001	-0.0014
Public investment efficiency	0.285	**-0.0067**	**-0.0062**	-0.0067	-0.0154	-0.0059	-0.0039	-0.0040	-0.0030

	Baseline	Absolute Deviations from Baseline							
Public Sector Downsizing, with Reallocation to		Benchmark		Endogenous ψ		Endogenous p		δ = 1.0	
Social Security/Benefit Spending:[b]		Impact	Steady-state	Impact	Steady-state	Impact	Steady-state	Impact	Steady-state
Share of unskilled workers	0.847	**-0.0001**	**0.0000**	-0.0001	-0.0009	-0.0001	-0.0004	-0.0001	0.0002
Effective share of skilled workers	0.141	**0.0001**	**0.0000**	0.0001	0.0007	0.0001	0.0003	0.0001	-0.0002
Effective share of public officials	0.002	**-0.0002**	**-0.0003**	-0.0002	-0.0003	-0.0002	-0.0003	-0.0003	-0.0003
Skilled unemployment rate	0.036	**0.0011**	**0.0026**	0.0011	0.0027	0.0011	0.0026	0.0010	0.0024
Unskilled unemployment rate	0.106	**0.0025**	**0.0086**	0.0025	0.0083	0.0025	0.0084	0.0024	0.0084
Headline unemployment rate	0.104	**0.0025**	**0.0084**	0.0025	0.0080	0.0025	0.0082	0.0024	0.0079
Share of corrupt officials	0.336	**0.0588**	**0.0637**	0.0595	0.0409	0.0534	0.0489	0.0435	0.0459
Social Security/Benefit rate	0.020	**0.0015**	**0.0004**	0.0015	0.0004	0.0015	0.0004	0.0015	0.0004
Growth rate of final output	0.047	**-0.0016**	**-0.0023**	-0.0016	-0.0009	-0.0016	-0.0020	-0.0015	-0.0022
Public investment efficiency	0.285	**-0.0069**	**-0.0064**	-0.0066	-0.0143	-0.0063	-0.0048	-0.0044	-0.0034

a/ A reduction in v_G by 10 percent.

b/ A reduction in v_G by 10 percent, leading to an increase in v_S by 10 percent.

Source: Authors' calculations.

Table 4

Policy Experiment Results for (i) Raising Social Security/Benefit Spending, and (ii) Raising Social Security/Benefit Spending, plus a reduction in training cost, both financed by a reallocation from other non-directly productive public spending

	Baseline	Absolute Deviations from Baseline							
		Benchmark		Endogenous ψ		Endogenous p		δ = 1.0	
Raising Social Security/Benefit Spending:[c]		Impact	Steady-state	Impact	Steady-state	Impact	Steady-state	Impact	Steady-state
Share of unskilled workers	0.847	**-0.0003**	**-0.0019**	-0.0003	-0.0019	-0.0003	-0.0018	-0.0003	-0.0019
Effective share of skilled workers	0.141	**0.0002**	**0.0016**	0.0002	0.0016	0.0002	0.0015	0.0002	0.0016
Effective share of public officials	0.002	**0.0000**	**0.0000**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Skilled unemployment rate	0.036	**0.0010**	**0.0029**	0.0010	0.0029	0.0010	0.0029	0.0010	0.0029
Unskilled unemployment rate	0.106	**0.0023**	**0.0079**	0.0023	0.0080	0.0023	0.0080	0.0023	0.0082
Headline unemployment rate	0.104	**0.0023**	**0.0077**	0.0023	0.0077	0.0023	0.0078	0.0022	0.0077
Share of corrupt officials	0.336	**-0.0034**	**-0.0059**	-0.0026	-0.0034	-0.0017	0.0009	-0.0019	-0.0037
Social Security/Benefit rate	0.020	**0.0015**	**0.0004**	0.0015	0.0004	0.0015	0.0004	0.0015	0.0004
Growth rate of final output	0.047	**-0.0016**	**-0.0008**	-0.0016	-0.0015	-0.0016	-0.0010	-0.0016	-0.0008
Public investment efficiency	0.285	**-0.0002**	**-0.0002**	0.0002	0.0008	-0.0004	-0.0009	-0.0003	-0.0004
	Baseline	Absolute Deviations from Baseline							
Raising Social Security/Benefit Spending,		Benchmark		Endogenous ψ		Endogenous p		δ = 1.0	
plus a Cut in Training Cost:[d]		Impact	Steady-state	Impact	Steady-state	Impact	Steady-state	Impact	Steady-state
Share of unskilled workers	0.847	**-0.0030**	**-0.0084**	-0.0030	-0.0075	-0.0030	-0.0073	-0.0030	-0.0079
Effective share of skilled workers	0.141	**0.0026**	**0.0071**	0.0026	0.0063	0.0026	0.0062	0.0026	0.0067
Effective share of public officials	0.002	**0.0000**	**0.0000**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Skilled unemployment rate	0.036	**0.0033**	**0.0065**	0.0033	0.0064	0.0033	0.0065	0.0033	0.0065
Unskilled unemployment rate	0.106	**-0.0002**	**0.0044**	-0.0002	0.0050	-0.0002	0.0052	-0.0001	0.0051
Headline unemployment rate	0.104	**0.0002**	**0.0047**	0.0002	0.0052	0.0003	0.0055	0.0003	0.0051
Share of corrupt officials	0.336	**-0.0572**	**-0.0796**	-0.0552	-0.0471	-0.0379	-0.0218	-0.0310	-0.0417
Social Security/Benefit rate	0.020	**0.0016**	**0.0004**	0.0016	0.0004	0.0016	0.0005	0.0016	0.0005
Growth rate of final output	0.047	**-0.0029**	**0.0011**	-0.0029	-0.0002	-0.0030	0.0000	-0.0030	0.0007
Public investment efficiency	0.285	**0.0017**	**0.0038**	0.0024	0.0137	-0.0008	-0.0026	-0.0012	-0.0002

c/ An increase in υ_S by 10 percent, financed by a 10 percent cut in υ_O.

d/ An increase in υ_S and μ each by 10 percent, financed by a 20 percent cut in υ_O.

Source: Authors' calculations.

Table 5

Policy Experiment Results for (i) a Reduction in Unskilled Workers' Union Mark-up, and (ii) Ambitious Social Reform Programme

		Absolute Deviations from Baseline							
	Baseline	Benchmark		Endogenous ψ		Endogenous p		δ = 1.0	
Reduction in Unskiled Workers' Union Mark-up:[e]		Impact	Steady-state	Impact	Steady-state	Impact	Steady-state	Impact	Steady-state
Share of unskilled workers	0.847	**0.0001**	**0.0001**	0.0001	0.0004	0.0001	0.0005	0.0001	0.0002
Effective share of skilled workers	0.141	**-0.0001**	**-0.0001**	-0.0001	-0.0004	-0.0001	-0.0004	-0.0001	-0.0002
Effective share of public officials	0.002	**0.0000**	**0.0000**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Skilled unemployment rate	0.036	**0.0000**	**0.0011**	0.0000	0.0011	0.0000	0.0010	0.0000	0.0011
Unskilled unemployment rate	0.106	**-0.0007**	**-0.0034**	-0.0007	-0.0032	-0.0007	-0.0031	-0.0007	-0.0033
Headline unemployment rate	0.104	**-0.0006**	**-0.0029**	-0.0006	-0.0028	-0.0006	-0.0026	-0.0006	-0.0027
Share of corrupt officials	0.336	**-0.0024**	**-0.0283**	-0.0028	-0.0173	-0.0016	-0.0046	-0.0011	-0.0132
Social Security/Benefit rate	0.020	**0.0001**	**0.0004**	0.0001	0.0004	0.0001	0.0004	0.0001	0.0004
Growth rate of final output	0.047	**0.0005**	**-0.0005**	0.0005	-0.0012	0.0005	-0.0010	0.0005	-0.0006
Public investment efficiency	0.285	**0.0005**	**0.0028**	0.0004	0.0064	0.0003	0.0001	0.0003	0.0011

		Absolute Deviations from Baseline							
Ambitious Social Reform:	Baseline	Benchmark		Endogenous ψ		Endogenous p		δ = 1.0	
Social Intervention & Job Creation:[f]		Impact	Steady-state	Impact	Steady-state	Impact	Steady-state	Impact	Steady-state
Share of unskilled workers	0.847	**-0.0058**	**-0.0152**	-0.0058	-0.0126	-0.0058	-0.0117	-0.0057	-0.0138
Effective share of skilled workers	0.141	**0.0049**	**0.0127**	0.0049	0.0106	0.0049	0.0099	0.0049	0.0117
Effective share of public officials	0.002	**-0.0001**	**-0.0002**	-0.0001	-0.0001	0.0000	-0.0001	0.0000	-0.0001
Skilled unemployment rate	0.036	**0.0057**	**0.0124**	0.0057	0.0121	0.0058	0.0121	0.0057	0.0122
Unskilled unemployment rate	0.106	**-0.0042**	**-0.0064**	-0.0042	-0.0047	-0.0041	-0.0039	-0.0040	-0.0048
Headline unemployment rate	0.104	**-0.0032**	**-0.0044**	-0.0032	-0.0028	-0.0031	-0.0020	-0.0030	-0.0030
Share of corrupt officials	0.336	**-0.1270**	**-0.2593**	-0.1242	-0.1373	-0.0806	-0.0546	-0.0678	-0.1283
Social Security/Benefit rate	0.020	**0.0019**	**0.0012**	0.0019	0.0012	0.0020	0.0012	0.0020	0.0012
Growth rate of final output	0.047	**-0.0032**	**0.0025**	-0.0032	-0.0004	-0.0033	-0.0011	-0.0033	0.0012
Public investment efficiency	0.285	**-0.0206**	**-0.0089**	-0.0197	0.0201	-0.0260	-0.0294	-0.0266	-0.0215

e/ A reduce of ξ^U by 10 percent, which translates to wage mark-up going from 1.23 times to 1.20 times.

f/ An increase in v_S by 10 percent, a training cost cut, μ, by 20 percent, and a reduction in ξ^U by 20 percent, which translates to 1.17 times of mark-up.

Source: Authors' calculations.

Table 6

Policy Experiment Results for (i) An Increase in the Share of Public Investment, and (ii) Ambitious Social Reform, plus an Increase in Share of Public Investment, with Models with Endogenous Threshold for Corruption

		Absolute Deviations from Baseline							
	Baseline	Benchmark		Endogenous ψ		Endogenous p		δ = 1.0	
An Increase in the Share of Public Investment:[g]		Impact	Steady-state	Impact	Steady-state	Impact	Steady-state	Impact	Steady-state
Share of unskilled workers	0.847	**0.0000**	**0.0000**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Effective share of skilled workers	0.141	**0.0000**	**0.0000**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Effective share of public officials	0.002	**0.0000**	**0.0000**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Skilled unemployment rate	0.036	**0.0000**	**0.0000**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Unskilled unemployment rate	0.106	**0.0000**	**0.0000**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Headline unemployment rate	0.104	**0.0000**	**0.0000**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Share of corrupt officials	0.336	**0.0000**	**0.0000**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Social Security/Benefit rate	0.020	**0.0000**	**0.0000**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Growth rate of final output	0.047	**0.0000**	**0.0000**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Public investment efficiency	0.285	**-0.0259**	**-0.0259**	-0.0259	-0.0259	-0.0259	-0.0259	-0.0423	-0.0428

		Absolute Deviations from Baseline									
Ambitious Social Reform, coupled with An Increase in the Share of Public Investment:[h]	Baseline	Benchmark (without switching)		Benchmark (with switching)		Endogenous ψ		Endogenous p		δ = 1.0	
		Impact	Steady-state	Impact	Steady-state	Impact	Steady-state	Impact	Steady-state	Impact	Steady-state
Share of unskilled workers	0.847	**-0.0058**	**-0.0152**	-0.0058	-0.0013	-0.0058	-0.0126	-0.0058	-0.0117	-0.0057	-0.0138
Effective share of skilled workers	0.141	**0.0049**	**0.0127**	0.0049	0.0011	0.0049	0.0106	0.0049	0.0099	0.0049	0.0117
Effective share of public officials	0.002	**-0.0001**	**-0.0002**	-0.0001	0.0000	-0.0001	-0.0001	0.0000	-0.0001	0.0000	-0.0001
Skilled unemployment rate	0.036	**0.0057**	**0.0124**	0.0057	0.0020	0.0057	0.0121	0.0058	0.0121	0.0057	0.0122
Unskilled unemployment rate	0.106	**-0.0042**	**-0.0064**	-0.0042	0.0006	-0.0042	-0.0047	-0.0041	-0.0039	-0.0040	-0.0048
Headline unemployment rate	0.104	**-0.0032**	**-0.0044**	-0.0032	0.0000	-0.0032	-0.0028	-0.0031	-0.0020	-0.0030	-0.0030
Share of corrupt officials	0.336	**-0.1270**	**-0.2593**	-0.1270	-0.3356	-0.1242	-0.1373	-0.0806	-0.0546	-0.0678	-0.1283
Social Security/Benefit rate	0.020	**0.0019**	**0.0012**	0.0019	0.0003	0.0019	0.0012	0.0020	0.0012	0.0020	0.0012
Growth rate of final output	0.047	**-0.0032**	**0.0025**	-0.0032	0.0031	-0.0032	-0.0004	-0.0033	-0.0011	-0.0033	0.0012
Public investment efficiency	0.285	**-0.0206**	**-0.0089**	-0.0206	0.7150	-0.0197	0.0201	-0.0260	-0.0294	-0.0266	-0.0215

g/ An increase in v_I by 10 percent, financed by a 10 percent cut in v_O.

h/ An increase in v_S band v_I by 10 percents, a training cost cut, μ, by 20 percent, and a reduction in ξ^U by 20 percent, which translates to 1.17 times of mark-up.

Source: Authors' calculations.

Figure 1
Public Sector Downsizing
(Absolute deviations from baseline)

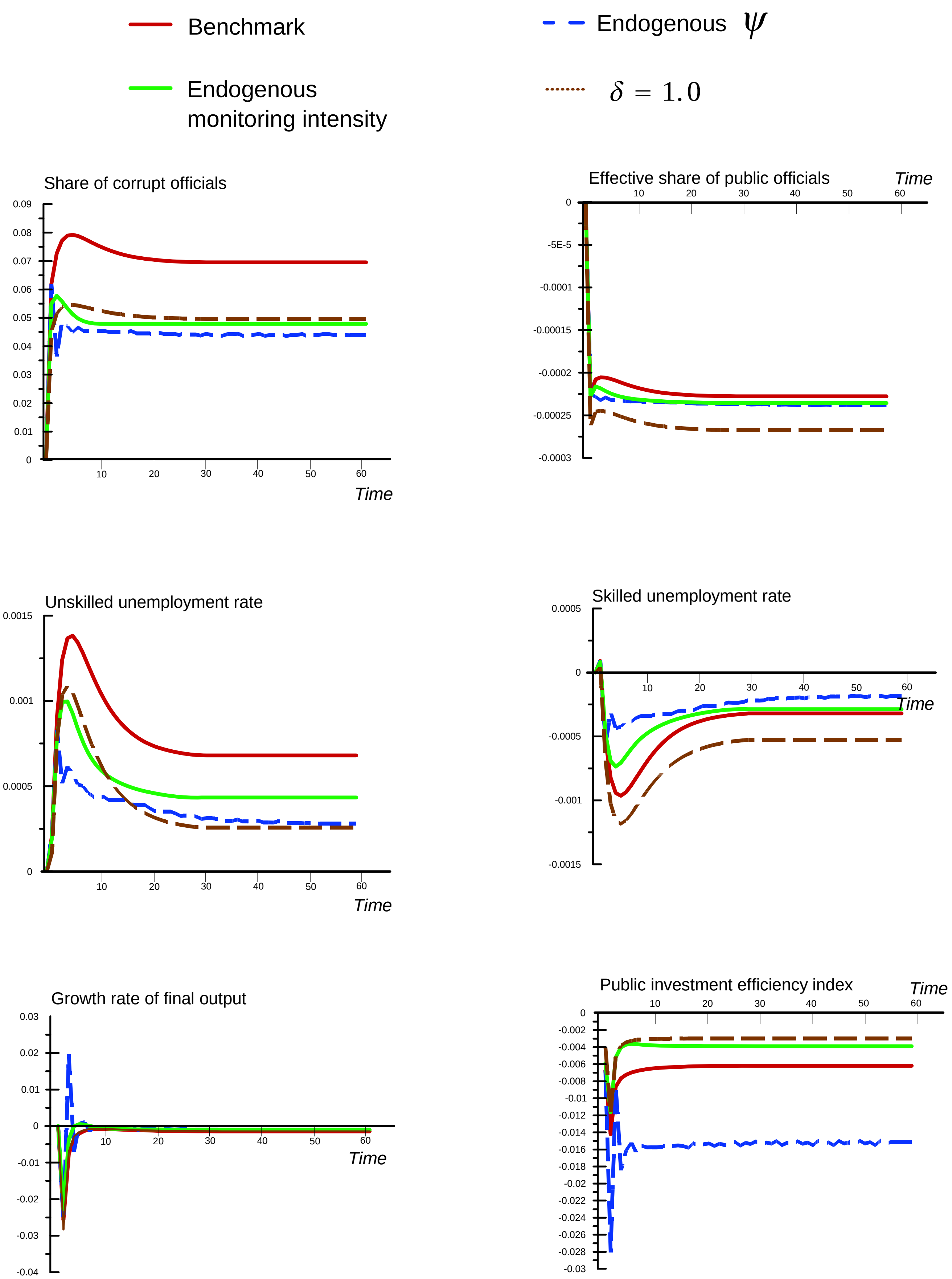

Figure 2

An Increase in the Share of Social Security / Benefit Spending

(Absolute deviations from baseline)

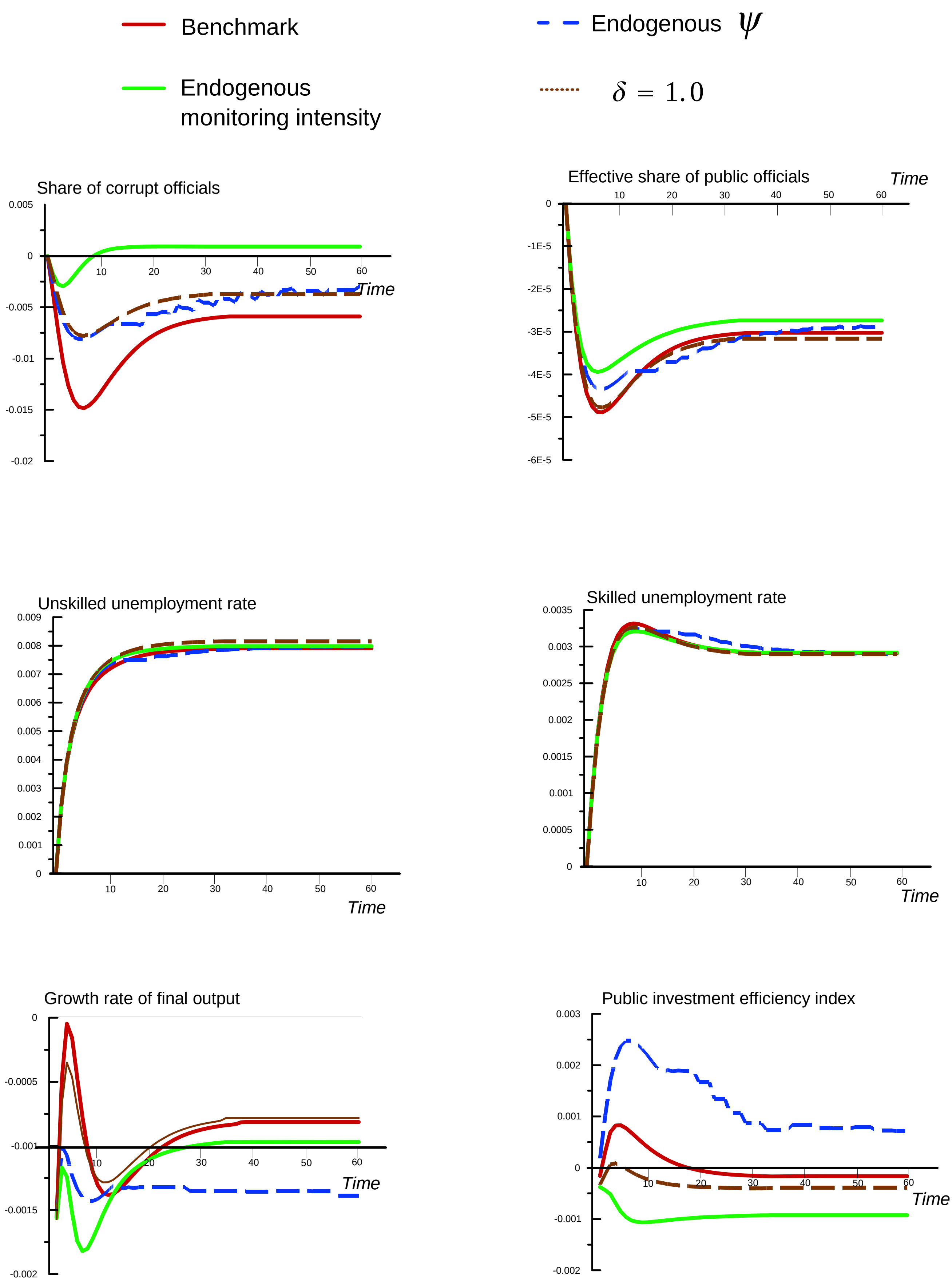

Figure 3

Reduction in Unskiled Workers' Union Wage Mark-up

(Absolute deviations from baseline)

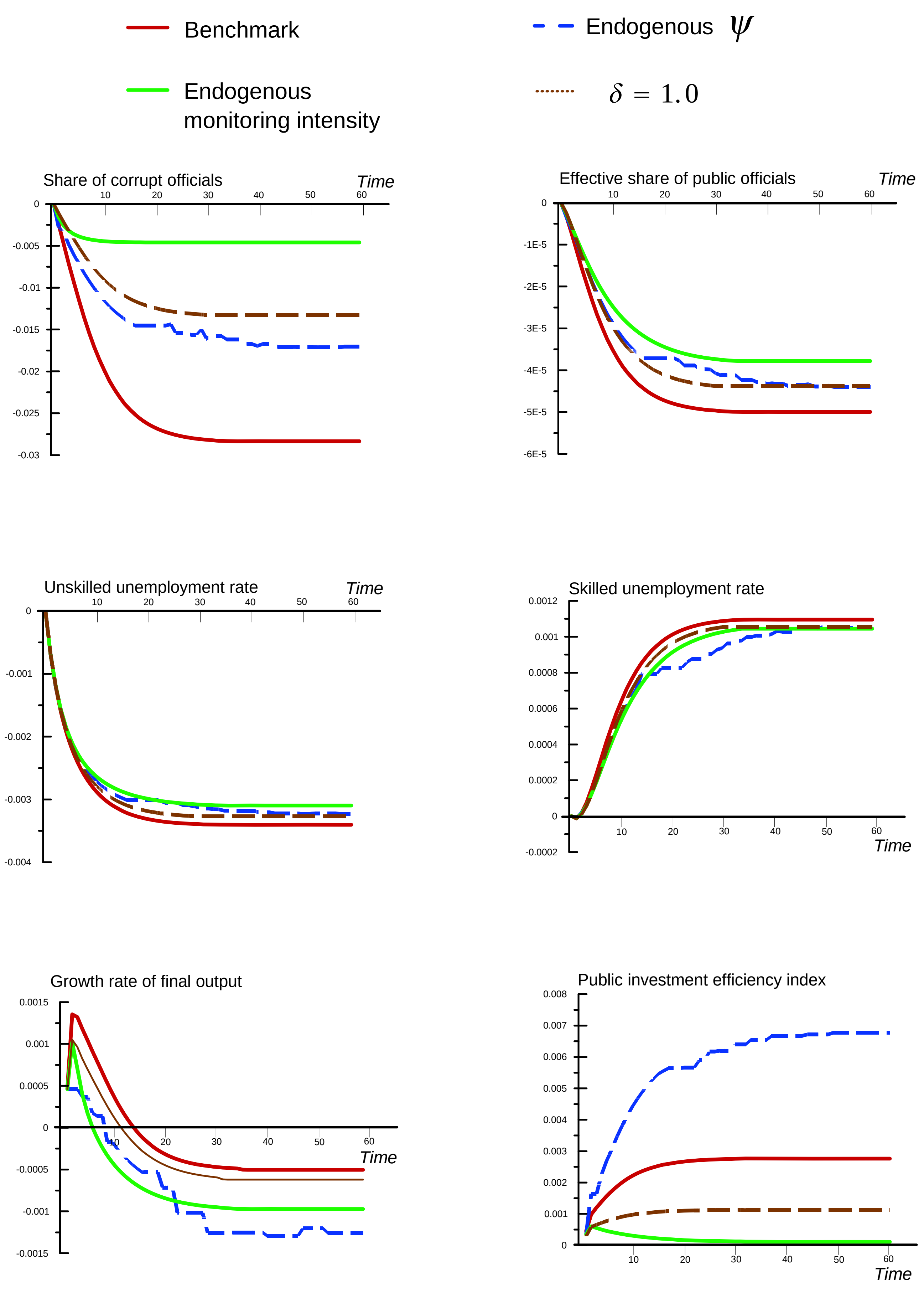

Figure 4

Ambitious Social Reform, coupled with an Increase in Share of Public Investment

(Absolute deviations from baseline)