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Public Investment and Corruption in an Endogenous Growth Model

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Abstract

High capital spending is favored by economists and politicians for its beneficial effects on economic growth. However, there is empirical research associating high levels of public investment with low economic growth due to corruption. I provide an endogenous growth model with Ramsey taxation that is consistent with this empirical finding. In the model, government maximizes the weighted average of consumers' utility and its own utility coming from expropriation of tax revenues. The weight determines the benevolence of the government. I show that a self-interested government sets a higher public-to-private-capital ratio than a benevolent one, reducing the productivity of public capital, in order to use more of the tax revenues for its own consumption. While a large public-to-private capital ratio increases the productivity of private investment, high taxes that come along with high public capital spending reduce the after-tax returns to private investment, causing the growth rate to be low.

Keywords: Corruption, Endogenous Growth, Public Investment, Ramsey Taxation.
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1 Introduction

This paper studies the relationship between political corruption and public investment, and how economic growth in the long run is affected by this relationship. Political corruption, as defined by *Transparency International*, is the abuse of entrusted power by political leaders for private gain, with the objective of increasing power or wealth. Given this definition, a benevolent government, whose sole purpose is to promote consumers' welfare, would never engage in corrupt activities. Hence, it is important to relax the assumption of a benevolent government in order to understand the link between political corruption, public investment, and economic growth. To this end, I build an endogenous growth model with a non-benevolent government, which decides on how much public capital to provide. Public capital, which affects the productivity of private capital, is financed through income taxes. The government chooses how much of the tax revenues to spend on public investment and how much to expropriate for its own consumption. The government maximizes a weighted average of consumers' welfare and its own welfare coming from expropriated tax revenues. The weight on consumers' welfare determines how benevolent the government is. If the weight on consumers' welfare is zero, then the government is totally self-interested, and if the weight is one then the government is totally benevolent. The weight can be any number between 0 and 1, implying that the government can be partially benevolent.

In equilibrium, government policies and the best response of private agents to those policies are determined, and they all depend on how benevolent the government is. Compared to a benevolent government, a self-interested government chooses a higher public-to-private capital ratio, which in turn implies higher tax rates, lower productive public investment spending, higher expropriation of tax revenues, lower private investment, and lower economic growth.

The government is assumed to be constrained by a period-by-period budget, which implies an upper bound on total embezzlement by the government in any period. This results in a dilemma for the corrupt politicians: they can either steal as much as they can in any period, leaving only a small amount of funds for the financing of the public capital, or they can invest in public capital so as to increase the productivity of private capital, and hence income, in the future. Increased income implies higher income tax revenues and more funds to embezzle in the future. Therefore, each type of government chooses an optimal growth rate through its policies that balances the cost of deferring expropriation of funds today and the benefit of increased tax revenues that can be embezzled in the future. This optimal growth rate is determined by the public-to-private capital ratio. I argue that a self-interested government chooses a higher public-to-private-capital ratio than a benevolent government, and that this results in lower economic growth in the long run.

Some implications of the model can be tested against the data. This exercise requires certain parameters and variables of the model to be interpreted in a way that allows comparison with observed and recorded data. For example, the degree of benevolence of the government in the model is interpreted as the degree of the lack of corruption in that country. Hence, a self-interested government in the model corresponds to a highly corrupt government in the data. A similar re-interpretation is needed for public investment. While the model distinguishes between productive public investment and expropriated tax revenues, it is hard to do so in the data. Expropriated tax revenues are recorded as part of government budget and affect several entries in the government budget. However, authors such as Tanzi and Davoodi (1997) and Keefer and Knack (2007) claim that most of the corrupt activities of governments are recorded as public investment. In accordance with these studies, expropriated tax revenues will be treated as part of public investment, and the model will predict high levels of total public investment in countries with high corruption. This prediction is consistent with the aforementioned papers.

1.1 Background and Related Literature

There is a large literature studying the effects of public spending on economic growth. Starting with Barro (1990), many theoretical papers introduce public capital into the production function to understand how much it would affect long-run growth. See Glomm and Ravikumar (1997) for a review of the early literature. Glomm and Ravikumar (1994) specifically focus on infrastructure investment; while Fisher and Turnovsky (1998) and Eicher and Turnovsky (2000) take a further step and look at the role of congestion of public capital. Most of the early theoretical literature is motivated by the empirical work of Aschauer (1989), among others, arguing that public investment has a substantial positive effect on growth. See Munnell (1992) for a review of the empirical literature. However, not all empirical papers agree with this claim. For example, Easterly and Rebelo (1993) emphasize the importance of distinguishing between different types of public spending. Devarajan, Swaroop, and Zou (1996) make the distinction between capital and current spending. They find that current expenditure has a positive effect on economic growth, whereas capital spending of governments has a negative effect on growth. They argue that developing countries have over-invested in public capital at the expense of current spending. While the findings of Ghosh and Gregoriou (2008) support this view, Bose, Haque, and Osborn (2007) find the opposite results. Kneller, Bleaney, and Gemmell (1999) differentiate between productive and non-productive public spending and find that while the former enhances growth, the latter does not. They also show that distortionary taxes decrease economic growth.

On the theory front, Turnovsky and Fisher (1995) provide a framework in which they distinguish between government consumption and government infrastructure investment, and show why the two would have different effects on economic growth. In their theoretical work, Park and Philippopoulos (2003) distinguish between productive and non-productive government spending and include redistributive transfers in their analysis. Recently, Economides, Park, and Philippopoulos (2011) add to this literature by differentiating between productive and non-productive public spending and showing how important congestion is on the determination of optimal government policy. They independently develop a model very similar to the one presented in this paper. They consider the case of a benevolent government deciding how to allocate tax revenues between productivity-enhancing and utility-enhancing public spending. In their case, consumers maximize a weighted average of utility from private consumption and utility from public goods. The main focus of their paper is characterizing the optimal fiscal policy when different types of public goods are subject to different degrees of congestion. In contrast, I consider a non-benevolent government deciding how much tax revenues to expropriate while providing productive public capital that ensures sustained economic growth, and hence, sustained source of corruption in the form of tax revenues.

This paper contributes to the literature on public spending and economic growth by introducing corruption as a reason why different governments choose varying levels of productive public goods and wasteful spending that does not benefit private agents. The literature reviewed above ignores the effect of corruption on public investment, which is explored mainly in empirical papers. For example, Tanzi and Davoodi (1997) maintain that corrupt governments choose high levels of public investment as a share of aggregate income. They claim that political corruption is often tied to capital projects. This is because the decisions regarding the budget and composition of capital are highly discretionary. Lack of competition in undertaking big capital projects and the difficulty in assessing the real cost and value of these projects make them suitable for corruption. The authors also argue that corruption reduces the productivity of public capital. Similarly, Keefer and Knack (2007) show that recorded levels of public investment are higher in corrupt countries. The model developed in this paper brings together these two strands of literature, and allows for the empirical results related to corruption and public investment to be tied to the theoretical insights from endogenous growth models.

There is also a large literature studying the direct relationship between corruption and economic growth, starting with Mauro (1995). Many authors conclude that corruption leads to lower economic growth (e.g. Tanzi and Davoodi (1997), Mauro (1997)). The contribution of the paper to this literature is to provide a theoretical framework, which focuses on public investment as the economic mechanism through which corruption affects growth.

To the best of my knowledge, this paper is the first attempt to explain the relationship between political corruption, public investment, and economic growth through a model that analyzes the behavior of different types of government. Haque and Kneller (2008) also analyze the link between these three variables, and they document the empirical relationship. They find that corruption raises the level of public investment but lowers the returns to it, making it ineffective in promoting economic growth. Their empirical findings are consistent with the results of my model.

This paper essentially brings together three strands of literature on public investment and growth, public investment and corruption, and corruption and growth. Most of the work done especially in the last two literatures is empirical and lacks a theoretical basis. This paper fills this theoretical gap in the literature.

1.2 The Road Map

The rest of the paper is organized as follows: I first set up the model and characterize the competitive equilibrium in Section 2. I then use the concept of Ramsey equilibrium to endogenize the policy choices of the government. After characterizing the balanced growth path outcomes, I move on to discussing the empirical implications of the model in Section 3. In Section 4, I describe the data used to test the empirical implications and show very basic relationships between the variables of interest. Section 5 concludes.

2 The model

2.1 Setup

In order to study the relationship between public investment and economic growth, I will use an endogenous growth model with public capital. The model is based on Barro (1990). There are a continuum of identical infinitely-lived individuals and a government. Each individual is born with an initial capital endowment of k_0. To keep the model simple, it is assumed that there is no labor market. There is a single nonstorable consumption good which is valued by the consumers. The representative individual maximizes her present discounted utility from consumption, where the discount rate $\beta \in (0, 1)$:

$$\sum_{t=0}^{\infty} \beta^t u(c_t) \tag{1}$$

Individuals rent capital, k, to firms and earn capital income at rate r, and pay income taxes at rate τ to the government. Therefore, their budget constraint is:

$$c_t + k_{t+1} - (1 - \delta_k)k_t = (1 - \tau_t)r_t k_t \qquad \forall t \tag{2}$$

where δ_k is the depreciation rate for private capital. Hence, given the representative individual's initial capital endowment, k_0, the sequence of rates of return to private capital, $\{r_t\}_0^\infty$, and the sequence of tax rates, $\{\tau_t\}_0^\infty$, the representative consumer's problem can be written as maximizing equation (1) subject to equation (2).

There are two factors of production in this economy: private capital and public capital. Each firm produces output, y_t, according to the following technology:

$$y_t = f(k_t, g_t) = Ak_t(\frac{g_t}{K_t})^\alpha \qquad \forall t \tag{3}$$

where $A > 0$, $0 < \alpha < 1$, g_t is the public capital stock, and K_t is the aggregate private capital stock. Individual private capital stock k and aggregate private capital stock K are differentiated to capture the effect of *congestion* on the marginal productivity of private capital. As the aggregate capital stock increases, public capital available per unit of private capital decreases, thereby reducing the marginal productivity of private capital. As argued in Barro and Sala-i Martin (1992), this functional form of production function corresponds to the case when public goods are rival but not excludable. According to these authors, this type of public goods includes highways, water and sewer systems, airports and harbors, courts, and even national defense and police.

Note that this production function implies constant returns to private capital as long as the government maintains a constant congestion of public services, i.e. a constant $\frac{g}{K}$ ratio. However, the aggregate production function $Y_t = AK_t(\frac{g_t}{K_t})^\alpha$ exhibits diminishing returns to aggregate private capital K for given public capital stock g, and this is due to congestion.[1]

The government is allowed to be non-benevolent and is assumed to maximize a weighted average of consumers' welfare and the utility it gets from expropriated resources:

$$\sum_{t=0}^{\infty} \beta^t \{(1-\theta)u(C_t) + \theta v(E_t)\} \tag{4}$$

where $\theta \in [0, 1]$ is the type of the government, and E is the expropriation by the government.

Here θ denotes the degree of government's benevolence. If $\theta = 0$, the government is totally benevolent and maximizes consumers' utility. If $\theta = 1$, the government is totally self-interested and maximizes the amount of resources it can divert from productive uses. The parameter θ is allowed to take on any value between 0 and 1, implying that the government can be partially benevolent. The type of the government is determined exogenously and does not change over time.

In reality, the degree of benevolence of a government can depend on many institutional, sociological, historical, and economic factors. Studying these factors is outside the scope of this paper, and hence, the type of the government will be treated as exogenous. Indices measuring the extent of corruption show that there is persistence in the extent of corruption over time.[2] Corrupt countries tend to stay corrupt. Similarly, clean economies persistently stay free of corruption.[3] Hence, θ for any country will be taken as constant over time.

The government levies distortionary income taxes to finance public investment, but it can expropriate part of the tax revenues for its own consumption. Hence, the government

[1] See Turnovsky and Fisher (1995), Eicher and Turnovsky (2000), Economides, Park, and Philippopoulos (2011) for detailed analyses of how congestion affects policy choices and equilibrium outcomes.

[2] For example, Corruption Perceptions Index values in 1995 and 2006 have a correlation coefficient of 0.93.

[3] See Mauro (2004) for two models with multiple equilibria that explain the persistence phenomena and its effects on economic growth.

budget constraint at any time t can be written as:

$$E_t + g_{t+1} - (1 - \delta_g) g_t = \tau_t r_t K_t \tag{5}$$

where δ_g is the depreciation rate of public capital. It is assumed that the government has a technology that converts tax revenues into public good. Also, it is assumed that $g_{t+1} \geq 0$ in every period. This implies that the maximum amount that can be expropriated at any time t equals total tax revenues at that period plus existing public capital net of depreciation.

A government policy is defined as a sequence of tax rates, public capital levels, and amount of expropriation for all $t \geq 0$. It is denoted by $\Pi = \{\tau_t, g_{t+1}, E_t\}_{t=0}^{\infty}$.

Finally, feasible allocations are described by the resource constraint:

$$C_t + K_{t+1} - (1 - \delta_k) K_t + g_{t+1} - (1 - \delta_g) g_t + E_t = A K_t \left(\frac{g_t}{K_t} \right)^{\alpha} \tag{6}$$

where C is the aggregate consumption spending in the economy.

2.2 Competitive Equilibrium

Competitive equilibrium describes the choices of consumers and firms as best response to government policies.

Definition 1 (Competitive Equilibrium) *For a given government policy* $\Pi = \{\tau_t, g_{t+1}, E_t\}_{t\geq 0}$*, and initial public and private capital stocks,* g_0 *and* k_0*, competitive equilibrium for this economy is an allocation* $\{c_t, k_{t+1}, C_t, K_{t+1}\}_{t\geq 0}$*, and a price* $\{r_t\}_{t\geq 0}$ *such that:*

1. *Given prices and policy, the allocation solves the consumer's maximization problem.*

2. *Price satisfies* $r_t = f_{kt} = A(\frac{g_t}{K_t})^{\alpha}$, $\forall t$.

3. *Government budget constraint (5) holds.*

4. Resource constraint (6) is satisfied.

2.2.1 Characterizing Competitive Equilibrium

The competitive equilibrium can be characterized by a set of seven equations. See Appendix A for details. The following two propositions simplify the characterization of competitive equilibrium by reducing it down to two equations. These propositions will be used in the next section to describe Ramsey equilibrium allocations.

Proposition 1 *The allocations in a competitive equilibrium satisfy the following:*

$$C_t + K_{t+1} - (1-\delta_k)K_t + g_{t+1} - (1-\delta_g)g_t + E_t = AK_t\left(\frac{g_t}{K_t}\right)^{\alpha} \tag{7}$$

$$u'(C_t) = \beta u'(C_{t+1})[\frac{C_{t+1}+K_{t+2}}{K_{t+1}}] \tag{8}$$

Proof. Constraint See Appendix B. ■

Equation (8) summarizes the best response of consumers and firms to government's choices and describes the conditions under which government policies can be implemented.

Proposition 2 *Given allocations and period-0 policies that satisfy* (7) *and* (8)*, one can construct policies and prices which, together with the given allocations and period-0 policies, constitute a competitive equilibrium.*

Proof. See Appendix B. ■

2.3 Ramsey Equilibrium

Competitive equilibrium allocations describe the behavior of private agents given government policy. However, government policies need to be endogenized. To that end, the setup of the model will be reinterpreted as a game, and additional assumptions regarding the timing of the game will be made. It will be assumed that the government moves first at time 0 and sets the stream of future policies for all time $t \geq 0$. Consumers make their decisions after they observe the government policy. This timing assumption implies that the government can fully commit to its policies at the beginning of the game and cannot change its actions after consumers have made their savings decisions.[4] The equilibrium notion used in this case is called Ramsey equilibrium.

Definition 2 (Ramsey Equilibrium) *Given initial capital stocks, g_0 and K_0, a Ramsey equilibrium is a government policy $\Pi^* = \{\tau_t^*, g_{t+1}^*, E_t^*\}_{t\geq 0}$, an allocation rule $\{C_t(\cdot), K_{t+1}(\cdot)\}_{t\geq 0}$, and a price function $\{r_t(\cdot)\}_{t\geq 0}$ such that:*

1. *Government policy Π^* solves:*

$$\max_{\Pi} \sum_{t=0}^{\infty} \beta^t \{(1-\theta)u(C_t(\pi)) + \theta v(E_t)\}$$

   subject to

$$E_t + g_{t+1} - (1-\delta_g)g_t = \tau_t r_t(\pi) K_t(\pi)$$

2. *For every policy $\pi \in \Pi$, the allocations $C(\pi)$ and $K(\pi)$, and the price system $r(\pi)$ constitute a competitive equilibrium.*

The resulting allocations in Ramsey equilibrium are called Ramsey allocations, and the resulting policies are called Ramsey policies. Propositions 1 and 2 will be used to characterize the Ramsey equilibrium.

[4]Commitment implies either institutional or reputational restrictions on government policy. One can argue that corrupt governments would not be restricted by reputational concerns, and institutions would be weak if corrupt governments are in power. This implies that government policies may be time-inconsistent in that the government may choose to levy higher taxes after the consumers make their savings decisions. This is a valid criticism. Extension of the model to an environment without commitment is left for future research. See Azzimonti-Renzo, Sarte, and Soares (2003) for the role commitment plays when a benevolent government finances public investment through income taxes.

2.3.1 Characterizing Ramsey Equilibrium

In order to characterize the Ramsey Equilibrium, I will set up a Ramsey Problem, following Chari and Kehoe (1999). Proposition 3 extends the results of Chari and Kehoe (1999) to the case with a non-benevolent government.

Ramsey Problem with a Non-Benevolent Government:

$$\max_{C_t, K_{t+1}, E_t, g_{t+1}} \sum_{t=0}^{\infty} \beta^t \{(1-\theta)u(C_t) + \theta v(E_t)\}$$

subject to

$$\begin{aligned} C_t + K_{t+1} - (1-\delta_k)K_t + g_{t+1} - (1-\delta_g)g_t + E_t &= AK_t\left(\frac{g_t}{K_t}\right)^{\alpha} && (9) \\ u'(C_t) &= \beta u'(C_{t+1})[\frac{C_{t+1}+K_{t+2}}{K_{t+1}}] && (10) \end{aligned}$$

Proposition 3 *Ramsey allocations and policies solve the Ramsey Problem with a non-benevolent government.*

Proof. This is a corollary of Propositions 1 and 2. Also see Chari and Kehoe (1999). ■

The Ramsey equilibrium can be characterized by a set of six equations, which describe the optimal behavior of the government and consumers at all time periods. See Appendix A for details.

2.4 Balanced Growth Path

The main focus of the paper is long-run growth, so the balanced growth path will be analyzed.[5] On a balanced growth path, the following ratios must be constant: $\frac{C_{t+1}}{C_t} = \gamma_C$, $\frac{E_{t+1}}{E_t} = \gamma_E$, $\frac{K_{t+1}}{K_t} = \gamma_K$, and $\frac{g_{t+1}}{g_t} = \gamma_g$ for all t.

[5]For the dynamic analysis of an endogenous growth model with public capital, see Futagami, Morita, and Shibata (1993).

Assuming $u(\cdot) = log(\cdot)$ and $v(\cdot) = log(\cdot)$, the balanced growth path can be characterized analytically.

Proposition 4 *Given initial private and public capital stocks, K_0 and g_0, the balanced growth path is characterized by the following conditions:*

- $\frac{C}{K} = (1-\beta)[1-\delta_g + A\alpha(\frac{g}{K})^{\alpha-1}]$
- $\frac{E}{K} = A(\frac{g}{K})^{\alpha} - (\frac{1}{\beta} + \frac{g}{K})\beta[1-\delta_g + A\alpha(\frac{g}{K})^{\alpha-1}] + (1-\delta_k) + (1-\delta_g)\frac{g}{K}$
- $\tau = 1 - \frac{[1-\delta_g + A\alpha(\frac{g}{K})^{\alpha-1}] - (1-\delta_k)}{A(\frac{g}{K})^{\alpha}}$
- $\gamma_C = \gamma_K = \gamma_E = \gamma_g = \gamma \equiv \beta[1-\delta_g + A\alpha(\frac{g}{K})^{\alpha-1}]$

where $\frac{g}{K}$ satisfies:

$$(1-\theta)\{A(\frac{g}{K})^{\alpha}-(\frac{1}{\beta}+\frac{g}{K})\beta[1-\delta_g+A\alpha(\frac{g}{K})^{\alpha-1}]+(1-\delta_k)+(1-\delta_g)\frac{g}{K}\}-\theta(1-\beta)[1-\delta_g+A\alpha(\frac{g}{K})^{\alpha-1}] =$$

$$\theta\beta[\delta_k - \delta_g + A\alpha(\frac{g}{K})^{\alpha-1} - A(1-\alpha)(\frac{g}{K})^{\alpha}]$$

Proof. See Appendix B. ■

The key ratio for the balanced growth path is the public-to-private capital ratio, $\frac{g}{K}$; all other variables are determined according to this ratio. Notice that this ratio depends on a number of things, including the depreciation rates of public capital and private capital (δ_g and δ_k), rate of time preference of the consumers and the government (β), public capital elasticity of output (α), and the type of the government (θ). Given the value of $\frac{g}{K}$, the consumption-private capital ratio and the expropriation-private capital ratio stay constant.

Remark 1 *On a balanced growth path, public-to-private capital ratio $\frac{g}{K}$ and economic growth rate are inversely related.*

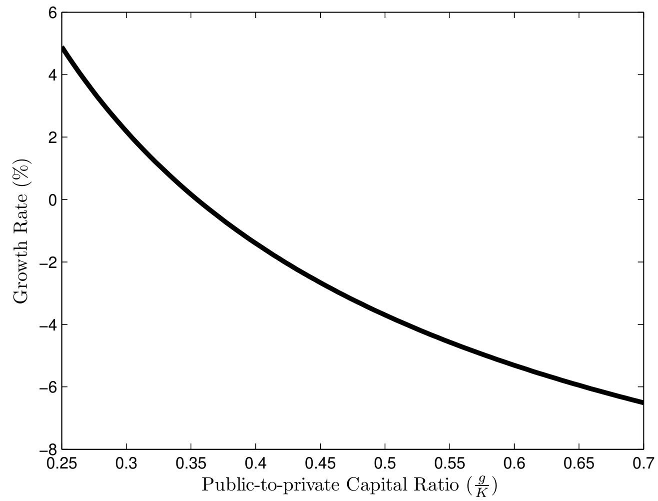

Figure 1: Growth and $\frac{g}{K}$. Parameter values are $A = \frac{1}{3}$, $\alpha = 0.25$, $\beta = 0.9$, and $\delta_k = \delta_g = 0.07$.

This remark might seem counter-intuitive at first. After all, public investment provides infrastructure to private capital, rendering it more productive. The effect of public capital on private capital is indeed positive in competitive equilibrium, when the growth rate is given by:

$$\gamma^{CE} = \beta[1 - \delta_k + (1 - \tau)A(\frac{g}{K})^{\alpha}] \tag{11}$$

In this case, the partial derivative of γ^{CE} is $\beta(1-\tau)A\alpha(\frac{g}{K})^{\alpha-1} > 0$. So, in a competitive equilibrium, the higher $\frac{g}{K}$, the higher the growth rate. Note that, in a competitive equilibrium, taxes are taken as given by consumers and firms. In Ramsey equilibrium, however, taxes are not constant, and they depend on $\frac{g}{K}$. The more public capital provided, the higher the taxes. While higher public capital is beneficial for economic growth, higher taxes have the opposite effect. Remark 1 implies that in Ramsey equilibrium, the increase in τ more than offsets the increase in $\frac{g}{K}$, and the growth rate decreases as a result.

For the rest of the results, I will first assume full depreciation, which simplifies the characterization of Ramsey equilibrium and allows for a clear exposition of the results. I will then show the more general case, with less than full depreciation.

Case 1 (Full Depreciation) *Assume* $\delta_g = \delta_k = 1$.

In this case the equation determining $\frac{g}{K}$ simplifies significantly:

$$\frac{g}{K} = \frac{\alpha}{(1-\theta)(1-\beta)+\beta(1-\alpha)} \tag{12}$$

Proposition 5 *A self-interested government sets a higher public-to-private capital ratio than a benevolent government does, for all $\beta < 1$, under full depreciation.*

Proof. From equation (12), if the government is benevolent, i.e. $\theta = 0$, it chooses:

$$(\frac{g}{K})^{BEN} = \frac{\alpha}{(1-\beta\alpha)} \tag{13}$$

If the government is self-interested, i.e. $\theta = 1$, it chooses:

$$(\frac{g}{K})^{SELF-INT} = \frac{\alpha}{\beta(1-\alpha)} \tag{14}$$

For $\beta < 1$, $(1-\beta\alpha) > \beta(1-\alpha)$. Hence, $\frac{\alpha}{(1-\beta\alpha)} < \frac{\alpha}{\beta(1-\alpha)}$. $\blacksquare$

Proposition 5 is the key result of the paper, and it requires an intuitive explanation. A close look at the production function shows that higher public capital always increases the amount of production; however, the effect of public capital on production depends on the public-to-private capital ratio. At the aggregate level, the production function is given by:

$$Y_t = AK_t(\frac{g_t}{K_t})^{\alpha} \tag{15}$$

Hence, $\frac{\partial Y_t}{\partial g_t} = A\alpha(\frac{g_t}{K_t})^{\alpha-1}$, and the higher $\frac{g_t}{K_t}$, the lower the marginal product of public capital, since $0 < \alpha < 1$.

If the marginal product of public capital is high, then marginal returns to investing in public capital is high, and the government has more incentives to use tax revenues for public investment rather than embezzling them. Therefore, a self-interested government, which prefers expropriation of funds to investing them would rather have the productivity of public capital low. The self-interested government can make public capital less productive by keeping the public-to-private capital ratio high. This is why g/K is inefficiently high when the government is self interested. This explanation is consistent with the empirical work of Tanzi and Davoodi (1997), asserting that corruption reduces the productivity of public capital. Proposition 5 could also explain why developing countries, many of which suffer from high levels of corruption, have over-invested in public capital, as Devarajan, Swaroop, and Zou (1996) argue.

Another point worth mentioning is why the benevolent government chooses $\frac{g}{K} = \frac{\alpha}{1-\beta\alpha}$. Readers familiar with the literature would recall that many endogenous growth models with public investment, starting with Barro (1990), find the optimal public investment-to-private capital ratio to be equal to the ratio of output elasticities of the two inputs, i.e. $\frac{\alpha}{1-\alpha}$. However, in the case of a benevolent government in this model, the optimal choice of the government is smaller than $\frac{\alpha}{1-\alpha}$. This is because in this model, unlike Barro (1990) and others, public investment is taken as a stock variable rather than a flow variable, and the government policy involves choosing next period's capital level rather than current investment. In the case of full depreciation, this means that in every period t, the government is choosing $\frac{g_{t+1}}{K_{t+1}}$ rather than $\frac{g_t}{K_t}$. Hence, Barro (1990)'s golden rule is discounted by the rate of time preference of the government and consumers.

Proposition 6 *When public capital and private capital fully depreciate*

(a) all types of governments set the same public investment share of output.

(b) the less benevolent a government, the higher the total public spending.

(c) the less benevolent a government, the higher the tax rate.

Proof. (a) Define public investment as $i_{gt} = g_{t+1} - (1 - \delta_g)g_t$, $\forall t$. It is shown in Appendix B that on the balanced growth path with full depreciation:

$$\frac{i_g}{Y} = \beta\alpha \tag{16}$$

Notice that this value does not depend on θ, so all types of governments choose the same share of public investment.

(b) Define total public spending as $i_{gt} + E_t$, $\forall t$. It is shown in Appendix B that on the balanced growth path with full depreciation:

$$\frac{i_g + E}{Y} = \beta\alpha + \theta(1 - \beta) \tag{17}$$

Hence, a bigger θ implies a larger total public spending. Given the government's budget constraint, this result implies that tax revenues are also higher when the government is corrupt. Note that this is not consistent with stylized facts provided by Tanzi and Davoodi (1997). However, this is to be expected, because the model does not incorporate any mechanism for tax payers to avoid paying taxes. In corrupt countries, tax revenues are usually low because of tax evasion, improper tax exemptions, and weak tax administration (Tanzi and Davoodi (1997)).

(c) Now consider the tax rate. It is shown in Appendix B that on the balanced growth path with full depreciation:

$$\tau = \beta\alpha + \theta(1 - \beta) \tag{18}$$

When the government is benevolent ($\theta = 0$):

$$\tau^{BEN} = \beta\alpha \tag{19}$$

When the government is totally self-interested, ($\theta = 1$):

$$\tau^{SELF-INT} = 1 - \beta + \beta\alpha \tag{20}$$

Notice that when the government is totally benevolent, all of the tax revenues are used for financing the productive portion of public investment. A self-interested government, on the other hand, uses only part of the tax revenues for the same amount of productive public investment. Another point to mention is that an impatient government expropriates more than a patient one. In other words, $\frac{\partial(\frac{E}{Y})}{\partial\beta} < 0$. With a low β, an impatient government does not wait for the tax base to increase over time with the growth rate. ■

Proposition 7 *When public and private capital fully depreciate*

(a) the less benevolent a government, the lower the private investment.

(b) the less benevolent a government, the lower the growth rate.

Proof. (a) Define aggregate private investment as $i_t = K_{t+1} - (1-\delta_k)K_t$, $\forall t$. It is shown in Appendix B that on the balanced growth path with full depreciation:

$$\frac{i_k}{Y} = \beta[(1-\theta)(1-\beta) + \beta(1-\alpha)] \tag{21}$$

Given equation (21), $\frac{\partial(i_k/Y)}{\partial\theta} = -\beta(1-\beta) < 0$.

(b) Using Proposition 4 and equation (12), growth rate can be found as:

$$\gamma = A\beta\alpha^{\alpha}[(1-\theta)(1-\beta) + \beta(1-\alpha)]^{1-\alpha} \tag{22}$$

Given the restrictions on all the parameters, the growth rate decreases with θ. ■

Case 2 (Less Than Full Depreciation) *Assume* $0 < \delta_g < 1$, $0 < \delta_k < 1$.

In this case, there is no way to simplify the formulas presented above. However, it is still possible to see how a benevolent government differs from a self-interested one. Table 1 shows how the values of the variables change with the degree of government's benevolence. These numbers are calculated for $A = \frac{1}{3}$, $\beta = 0.9$, $\alpha = 0.25$, $\delta_k = 0.07$, and $\delta_g = 0.07$.

Table 1: **Balanced Growth Path Values**

θ	**0**	**0.10**	**0.25**	**0.50**
g/K	0.28	0.30	0.33	0.40
g/Y	1.17	1.22	1.32	1.52
K/Y	4.12	4.05	3.95	3.77
i^g/Y	0.12	0.11	0.10	0.08
E/Y	0	0.06	0.15	0.30
τ	0.12	0.18	0.25	0.38
i^k/Y	0.41	0.37	0.31	0.21
Growth Rate	3%	2.1%	1%	-1.5%

In this case, productive portion of public spending is no longer the same across different types of government. The less benevolent a government, the less productive public investment spending. The other variables are related to θ in the same way they were in the case of full depreciation.

3 Empirical Implications of the Model

Some of the empirical implications of the model are already tested against the data by other researchers. For example, the implication that corrupt countries would have low growth rates has been demonstrated by Mauro (1995), among others.

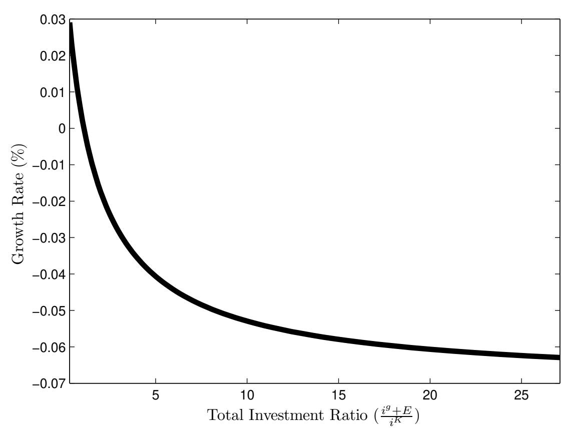

Figure 2: Total Public-to-private Investment Ratio and Growth. Parameter values same as in Figure 1.

Other implications of the model are not documented. The model predicts that countries with high total public-to-private ratio would have low economic growth (see Figure 2). The model also implies that productive public investment and expropriated tax revenues are inversely correlated (see Figure 3). A benevolent government would choose a high productive public investment share of output and would not embezzle resources for its own use. A self-interested government, on the other hand, would choose a lower productive public investment and use a large part of tax revenues for non-productive purposes. This means that if the total public investment observed is high, then it is likely that most of this public investment is non-productive, aimed at providing private returns for politicians. Figure 4 depicts this relationship.

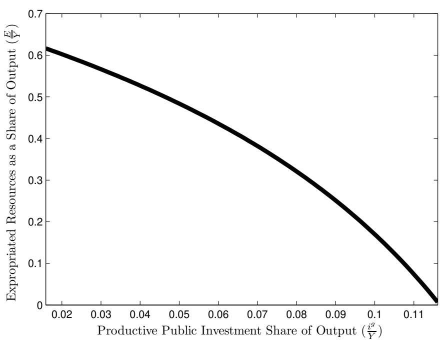

Figure 3: Productive Public Investment and Expropriated Resources as a Share of Output. Parameter values same as in Figure 1.

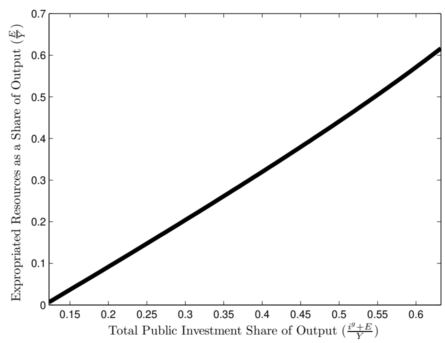

Figure 4: Total Public Investment Share of Output and Expropriated Resources as a Share of Output. Parameter values same as in Figure 1.

Finally, the model predicts that corrupt governments would set higher taxes, which cause economic growth rates to suffer.

My aim in the next section is to show that the untested implications of the model are consistent with the data. Rigorous empirical work studying the effect of corruption on public-to-private investment ratio and the effect of this ratio on economic growth is left for future research.

4 Data

The key variable in the model is the public-to-private capital ratio. However, public capital stock and private capital stock are not available for most countries. As a proxy to g/K, I use the public-to-private investment ratio. To calculate this ratio, I use the public investment and private investment shares of GDP for various countries reported by Everhart and Sumlinski (2001). In addition, I use the Easterly (2001) data set and OECD data to fill in the data for additional countries. These data sets cover a wide range of countries over 1970-2000. Since the focus of this paper is on the long-run, I take the average of public and private investment shares of output for each country during that period.

I use Heston, Summers, and Aten (2006) data for annual growth rates in real GDP per capita (in 2000 constant prices) between 1970-2000. I calculate the average annual growth rate during that period for each country. The measure of corruption I use is Transparency International's Corruption Perceptions Index (CPI) for 2000.[6] The CPI ranks countries by their perceived levels of public sector corruption, as determined by expert assessments and opinion surveys. It scores countries on a scale from zero to ten, with ten indicating a highly clean country and zero indicating a highly corrupt country. While CPI data is available starting from 1994, CPI values are not comparable across time. Hence, rather than taking the average CPI values for between 1994-2000, I only look at the CPI values for 2000. Earlier years include fewer countries.

There are 64 countries in the whole sample.[7] The complete list of countries included is

[6]The methodology of corruption indices, what they exactly measure, and their use in empirical work have received criticism in the literature. See Knack (2007) for a review of problems associated with measures of corruption. However, many authors working on corruption have used them to measure different aspects of corruption. For example, Fredriksson and Svensson (2003) use the corruption index of the *International Country Risk Guide* to measure the weight politicians put on the bribes they receive relative to social welfare. Mauro (1998), on the other hand, uses the same index to measure the extent of lucrative opportunities public spending on education provides to government officials. In this paper, I use CPI to measure the weight politicians put on their own welfare relative to the welfare of the consumers.

[7]In an earlier version of the paper, I used the data set of Easterly and Rebelo (1993). That data set covered only the period 1970-1998, and it included 86 countries. The countries included in that data set are significantly different than the ones covered in the data set I use in this version. However, the results are very similar for both data sets, which reinforces the validity of the results.

in Appendix C. Table 2 presents descriptive statistics of the variables analyzed.

Table 2: **Descriptive Statistics**

	Mean	**Std. Dev.**	**Minimum**	**Maximum**
Whole Sample (64 Countries)				
Public Investment Share (%)	6.51	3.92	1.75	19.56
Private Investment Share (%)	16.18	5.68	4.16	27.25
Public-to-private Capital Ratio	0.64	0.60	0.09	3.30
Growth Rate (%)	1.92	1.71	-3.73	7.28
2000 Corruption Perceptions Index	5.09	2.48	1.20	10
Top Marginal Tax Rate (%)	3.57	1.86	0.50	8.10
Advanced Countries[a] (24 Countries)				
Public Investment Share (%)	3.24	0.89	1.75	5.42
Private Investment Share (%)	21.35	3.02	16.10	27.25
Public-to-private Capital Ratio	0.19	0.10	0.09	0.64
Growth Rate (%)	2.40	1.14	0.13	6.32
2000 Corruption Perceptions Index	7.70	1.71	4	10
Top Marginal Tax Rate (%)	2.57	1.57	0.50	7.42
Developing Countries[a] (40 Countries)				
Public Investment Share (%)	8.47	3.72	2.37	19.56
Private Investment Share (%)	13.8	4.52	4.16	26.82
Public-to-private Capital Ratio	0.91	0.61	0.17	3.30
Growth Rate (%)	1.63	1.93	-3.73	7.28
2000 Corruption Perceptions Index	3.53	1.24	1.20	7.40
Top Marginal Tax Rate (%)	4.25	1.75	0.63	8.10
Least Corrupt Countries[b] (11 Countries)				
Public Investment Share (%)	3.14	0.69	1.75	4.08
Private Investment Share (%)	20.32	3.06	16.10	26.25
Public-to-private Capital Ratio	0.18	0.05	0.10	0.25
Growth Rate (%)	2.20	0.77	1.09	3.56
2000 Corruption Perceptions Index	9.16	0.46	8.60	10.00
Top Marginal Tax Rate (%)	2.45	1.86	0.50	7.42
Most Corrupt Countries[b] (11 Countries)				
Public Investment Share (%)	8.24	4.28	3.50	19.56
Private Investment Share (%)	12.90	5.46	6.49	26.82
Public-to-private Capital Ratio	0.89	0.48	0.17	1.93
Growth Rate (%)	0.97	1.45	-1.04	3.93
2000 Corruption Perceptions Index	2.17	0.52	1.20	2.70
Top Marginal Tax Rate (%)	4.72	2.50	0.63	8.10

[a] *According to the classification of the IMF. See Appendix C for the list of advanced countries.*

[b] *Top and bottom 11 countries according to the Corruption Perceptions Index (2000). See Appendix C for the list of these countries.*

To test the key implication of the model, I look at the correlation between corruption and public-to-private investment ratio. For ease of exposition, I change the measure of corruption to $10 - CPI$, so that higher values of the corruption measure correspond to high levels of corruption. As Figure 5 shows, corruption and the public-to-private investment ratio are positively related. Since $\frac{g}{K}$ is a measure of congestion in the model, this result can also be interpreted as congestion being lower in countries with corrupt governments.

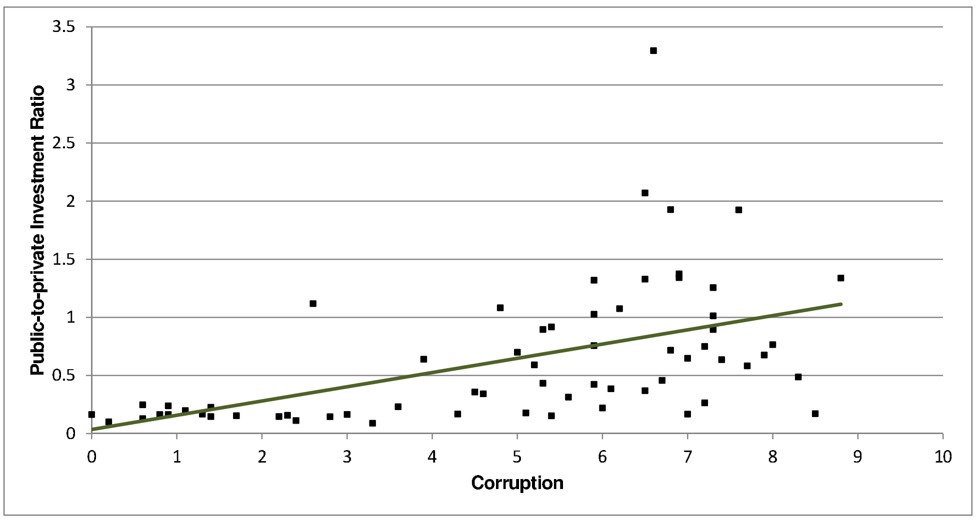

Figure 5: Public-to-private Investment Ratio and Corruption in the data.

Figure 6 shows the relationship between the public-to-private investment ratio and the growth rate.

Figure 7 depicts the relationship between corruption and public investment share of output. This positive relationship is in line with the model's results. Corrupt governments inflate the amount of public investment by reducing the productive public investment and increasing the amount of funds expropriated. Keefer and Knack (2007) find a similar result and claim that public investment reported should not be used for policy suggestions because the reported public investment data is an overestimation of the actual productive public investment.

To test the implications of the model regarding tax rates, I use the top marginal tax rate data from Gwartney, Hall, and Lawson (2011). This data set reports top marginal tax

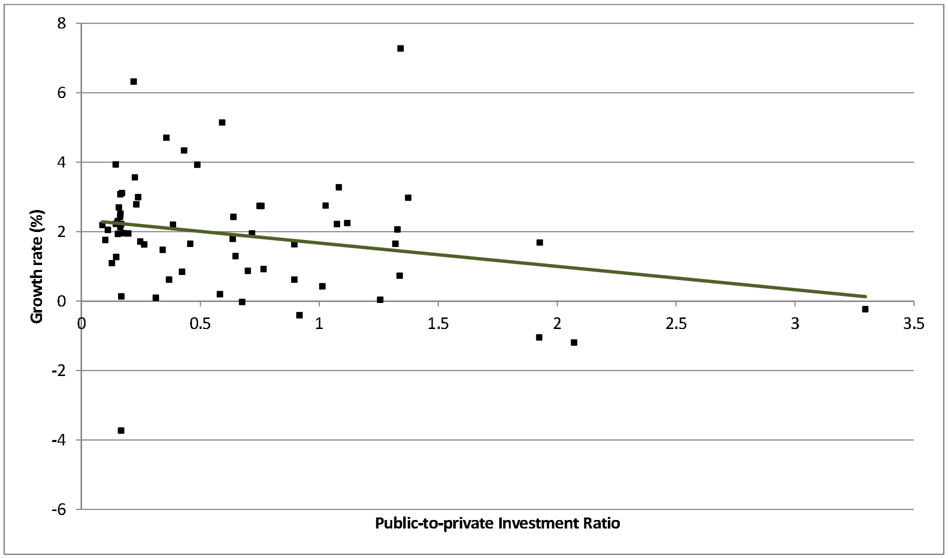

Figure 6: Public-to-private Investment Ratio and Growth Rate in the data.

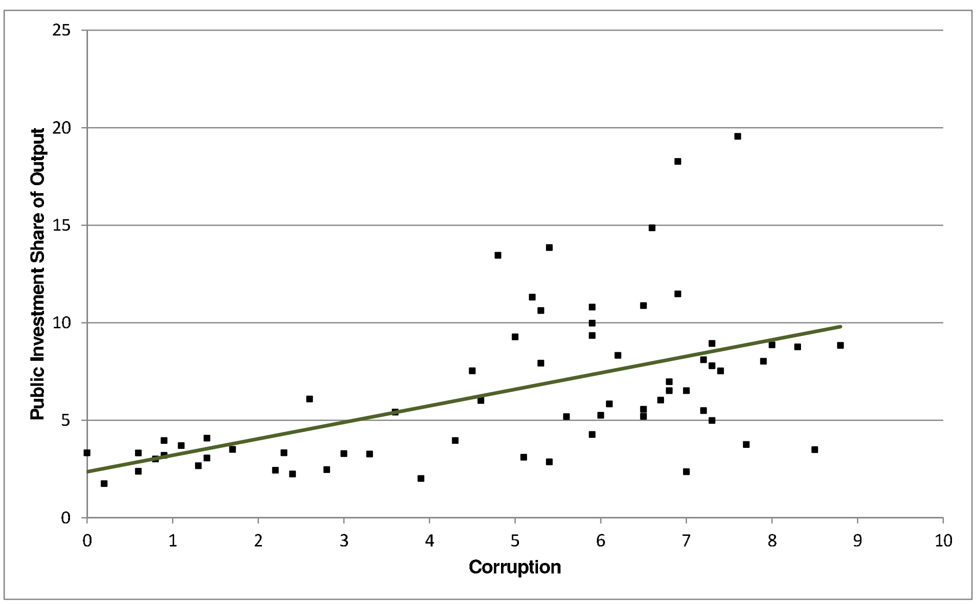

Figure 7: Public Investment Share of Output and Corruption in the data.

rates for every five years during 1970-2000. I calculate the average marginal tax rate for each country. Figure 8 demonstrates the positive relationship between corruption and top marginal tax rate, as implied by the model. The signs of correlation between tax rate and the other variables are also consistent with the implications of the model.

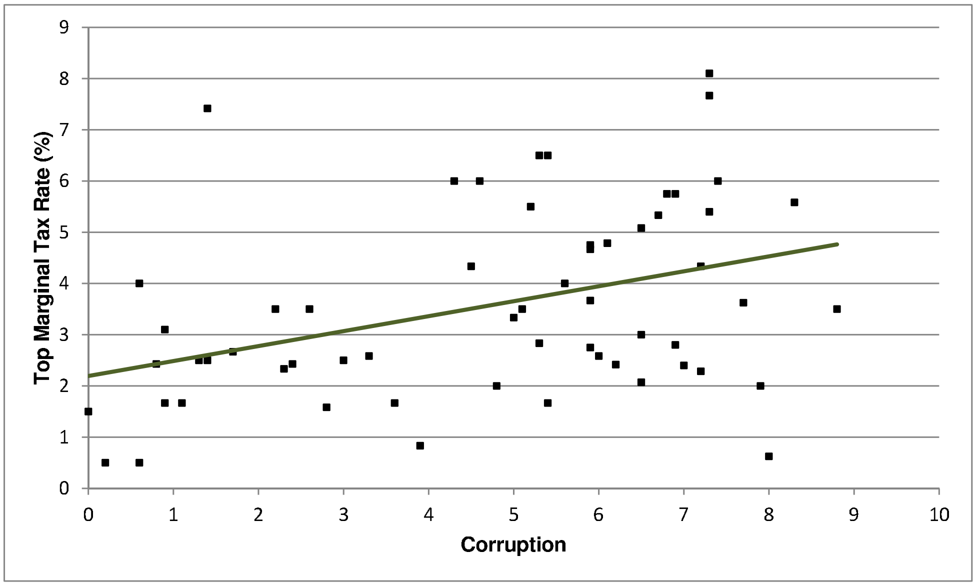

Figure 8: Top Marginal Tax Rate and Corruption in the data.

Table 3 summarizes the correlation coefficients for all the variables. Note that all coefficients are statistically significant at the 90% confidence level except for the ones noted in the table.

Table 3: **Correlation Coefficients**

	$(\mathbf{i^g + E)/Y}$	$\mathbf{i^k/Y}$	$\mathbf{g/K}$	**Growth Rate**	**Corruption**	**Tax Rate**
$\mathbf{(i^g + E)/Y}$	1					
$\mathbf{i^k/Y}$	-0.52	1				
$\mathbf{g/K}$	0.75	-0.70	1			
Growth Rate	0.02*	0.34	-0.24	1		
Corruption	0.54	-0.57	0.51	-0.21@	1	
Tax Rate	0.33	-0.28	0.18+	-0.12*	-0.39	1

* *Not statistically significant.*

@ *Statistically significant almost at the 90% confidence level.*

\+ *Significant at the 80% confidence level.*

5 Concluding remarks

This paper provides a theoretical framework to understand the link between public investment, corruption, and economic growth. The economic mechanism suggested by the model is that a self-interested government provides an inefficiently high level of public capital, which reduces the productivity of public investment and provides room for corrupt spending by the government. Low levels of congestion of public capital (high public-to-private capital ratio) increases the productivity of private investment. However, higher taxes that come with higher public capital levels cause economic growth rate to suffer. The model predicts that corruption comes with high public-to-private capital ratio, high recorded public investment (which includes corrupt spending), high tax rates, low private investment, and low economic growth.

An interesting extension of the model would be to consider the case when the government does not have access to a commitment technology and to compare the results to those of Azzimonti-Renzo, Sarte, and Soares (2003).

Appendix A - Characterization of Equilibria

Characterizing Competitive Equilibrium

Let λ_t be the Lagrange multiplier on the time-t consumer's budget constraint (denoted Cons-BC below). The following equations characterize the competitive equilibrium:

$$
\begin{array}{llcll}
\text{Cons-BC:} & C_t + K_{t+1} - (1-\delta_k)K_t & = & (1-\tau_t)r_t K_t & \forall t \\
\text{Cons-Euler:} & \frac{\beta u'(c_{t+1})}{u'(c_t)} & = & \frac{1}{(1-\tau_{t+1})r_{t+1}+1-\delta_k} & \forall t \\
\text{Price:} & r_t & = & A\left(\frac{g_t}{K_t}\right)^{\alpha} & \forall t \\
\text{GBC:} & E_t + g_{t+1} - (1-\delta_g)g_t & = & \tau_t r_t K_t & \forall t \\
\text{Feasibility:} & C_t + K_{t+1} - (1-\delta_k)K_t + g_{t+1} - (1-\delta_g)g_t + E_t & = & AK_t\left(\frac{g_t}{K_t}\right)^{\alpha} & \forall t \\
\text{TVC1:} & \lim_{t\to\infty} \lambda_t K_t & = & 0 & \\
\text{TVC2:} & \lim_{t\to\infty} \lambda_t g_t & = & 0 &
\end{array}
$$

Characterizing Ramsey Equilibrium

Let $\beta^t\lambda_t$ and $\beta^t\mu_t$ be the Lagrange multipliers on equations (9) and (10), respectively. Then the following equations characterize the Ramsey Equilibrium:

$$\begin{aligned}
(1-\theta)u'_t + \lambda_t + \mu_t u''_t - \mu_{t-1}u''_t[\tfrac{C_t+K_{t+1}}{K_t}] - \mu_{t-1}u'_t\tfrac{1}{K_t} &= 0\\
\lambda_t - \beta\lambda_{t+1}[1-\delta_k + A(1-\alpha)\left(\tfrac{g_{t+1}}{K_{t+1}}\right)^\alpha] + \beta\mu_t u'_{t+1}[\tfrac{C_{t+1}+K_{t+2}}{K_{t+1}^2}] - \mu_{t-1}\tfrac{u'_t}{K_t} &= 0\\
\theta v'_t + \lambda_t &= 0\\
\lambda_t - \beta\lambda_{t+1}[1-\delta_g + A\alpha\left(\tfrac{g_{t+1}}{K_{t+1}}\right)^{\alpha-1}] &= 0\\
C_t + K_{t+1} - (1-\delta_k)K_t + g_{t+1} - (1-\delta_g)g_t + E_t &= AK_t\left(\tfrac{g_t}{K_t}\right)^\alpha\\
\beta u'(C_{t+1})[\tfrac{C_{t+1}+K_{t+2}}{K_{t+1}}] &= u'(C_t)
\end{aligned}$$

Appendix B - Proofs of Propositions

Proof of Proposition 1

The first constraint, the feasibility constraint, is part of the definition of CE. The second one is obtained by plugging GBC, Price, and Feasibility in Cons-Euler.

$$\begin{aligned}
u'(C_t) &= \beta u'(C_{t+1})[(1-(\frac{E_{t+1}+g_{t+2}-(1-\delta_g)g_{t+1}}{r_{r+1}K_{t+1}}))r_{t+1}+1-\delta_k]\\
u'(C_t) &= \beta u'(C_{t+1})[A(\frac{g_{t+1}}{K_{t+1}})^\alpha - (\frac{E_{t+1}+g_{t+2}-(1-\delta_g)g_{t+1}}{A(\frac{g_{t+1}}{K_{t+1}})^\alpha K_{t+1}})A(\frac{g_{t+1}}{K_{t+1}})^\alpha + 1-\delta_k]\\
u'(C_t) &= \beta u'(C_{t+1})[\frac{A(\frac{g_{t+1}}{K_{t+1}})^\alpha K_{t+1} - E_{t+1} - g_{t+2} + (1-\delta_g)g_{t+1}}{K_{t+1}} + 1-\delta_k]\\
u'(C_t) &= \beta u'(C_{t+1})[\frac{C_{t+1}+K_{t+2}-(1-\delta_k)K_{t+1}}{K_{t+1}} + 1-\delta_k]\\
u'(C_t) &= \beta u'(C_{t+1})[\frac{C_{t+1}+K_{t+2}}{K_{t+1}}]
\end{aligned}$$

Proof of Proposition 2

Aggregate allocations $\{C_t, K_t\}_{t\geq 0}$, initial conditions g_0 and K_0, and first-period policies g_1, τ_0 and E_0 are given. Prices $\{r_t\}_{t=0}^\infty$ and policies $\{\tau_t, E_t, g_{t+1}\}_{t=1}^\infty$ need to be constructed. To this end first-order conditions will be used. Given the assumptions on the utility function of consumers, the first-order conditions are both necessary and sufficient for consumer and firm maximization.

The following four equations can be used to construct r_t, τ_t, E_t, and g_{t+1} at each time t:

$$\begin{aligned}
r_t &= A\left(\frac{g_t}{K_t}\right)^{\alpha} && (23)\\
\tau_{t+1} &= 1-\left[\frac{u'_t}{\beta u'_{t+1}}-1+\delta_k\right]\frac{1}{A\left(\frac{g_{t+1}}{k_{t+1}}\right)^{\alpha}} && (24)\\
C_t+K_{t+1}-(1-\delta_k)K_t+g_{t+1}-(1-\delta_g)g_t+E_t &= AK_t\left(\frac{g_t}{K_t}\right)^{\alpha} && (25)\\
g_{t+1}-(1-\delta_g)g_t+E_t &= A(1-\tau_t)K_t\left(\frac{g_t}{K_t}\right)^{\alpha} && (26)
\end{aligned}$$

Proof of Proposition 4

As shown in Appendix A, Ramsey Problem is characterized by the following equations:

$$\begin{aligned}
\frac{(1-\theta)}{C_t}+\lambda_t-\frac{\mu_t}{C_t^2}+\frac{\mu_{t-1}}{C_t^2}[\frac{C_t+K_{t+1}}{K_t}]-\frac{\mu_{t-1}}{C_tK_t} &= 0 && (27)\\
\lambda_t-\beta\lambda_{t+1}[1-\delta_k+A(1-\alpha)\left(\frac{g_{t+1}}{K_{t+1}}\right)^{\alpha}]+\beta\frac{\mu_t}{C_{t+1}}[\frac{C_{t+1}+K_{t+2}}{K_{t+1}^2}]-\frac{\mu_{t-1}K_t}{C_t} &= 0 && (28)\\
\frac{\theta}{E_t}+\lambda_t &= 0 && (29)\\
\lambda_t-\beta\lambda_{t+1}[1-\delta_g+A\alpha\left(\frac{g_{t+1}}{K_{t+1}}\right)^{\alpha-1}] &= 0 && (30)\\
C_t+K_{t+1}-(1-\delta_k)K_t+g_{t+1}-(1-\delta_g)g_t+E_t &= AK_t\left(\frac{g_t}{K_t}\right)^{\alpha} && (31)\\
\frac{\beta}{C_{t+1}}[\frac{C_{t+1}+K_{t+2}}{K_{t+1}}] &= \frac{1}{C_t} && (32)
\end{aligned}$$

On a balanced growth path, the following ratios must be constant: $\frac{C_{t+1}}{C_t}=\gamma_C$, $\frac{E_{t+1}}{E_t}=\gamma_E$, $\frac{K_{t+1}}{K_t}=\gamma_K$, and $\frac{g_{t+1}}{g_t}=\gamma_g$ for all t.

Plug (29) in (30):

$$\frac{E_{t+1}}{E_t}=\beta[1-\delta_g+A\alpha\left(\frac{g_{t+1}}{K_{t+1}}\right)^{\alpha-1}]$$

In order for this ratio to be constant over time, $\frac{g_t}{K_t}$ must be constant for all t. Denote this ratio by $X=\frac{g}{K}$. Then:

$$\gamma_E=\beta[1-\delta_g+A\alpha X^{\alpha-1}]$$

Equation (32) on balanced growth path implies:

$$\frac{C_t}{K_t}+\gamma_K=\frac{\gamma_C}{\beta}$$

So $\frac{C_t}{K_t}$ is a constant for all t, hence $\gamma_C=\gamma_K$. So, on balanced growth path:

$$\frac{C}{K}=(\frac{1-\beta}{\beta})\gamma_K \tag{33}$$

Rewrite equation (31):

$$\frac{C_t}{K_t} + \frac{K_{t+1}}{K_t} - (1-\delta_k) + \frac{g_{t+1}}{K_t} - (1-\delta_g)\frac{g_t}{K_t} + \frac{E_t}{K_t} = A\left(\frac{g_t}{K_t}\right)^{\alpha}$$

On balanced growth path:

$$(\frac{1-\beta}{\beta})\gamma_K + \gamma_K - (1-\delta_k) + X\gamma_K - (1-\delta_g)X + \frac{E_t}{K_t} = AX^{\alpha}$$

So, $\frac{E_t}{K_t}$ is a constant for all t; hence $\gamma_E = \gamma_K$ and:

$$\frac{E}{K} = AX^{\alpha} - (\frac{1}{\beta} + X)\gamma_K + (1-\delta_k) + (1-\delta_g)X \tag{34}$$

Now consider (27). Plug (29) in (27):

$$\frac{(1-\theta)}{C_t} - \frac{\theta}{E_t} - \frac{\mu_t}{C_t^2} + \frac{\mu_{t-1}}{C_t^2}[\frac{C_t + K_{t+1}}{K_t}] - \frac{\mu_{t-1}}{C_t}\frac{1}{K_t} = 0$$

Multiply it by K_t and consider the balanced growth path:

$$\frac{(1-\theta)K}{C} - \frac{\theta K}{E} - \frac{\mu_t K}{C_t C} + \frac{\mu_{t-1}K}{C_t C}[\frac{C_t + K_{t+1}}{K_t}] - \frac{\mu_{t-1}}{C_t} = 0$$

Rewrite it:

$$\frac{(1-\theta)K}{C} - \frac{(1-\gamma)K}{E} - \frac{\mu_t}{C_t}\frac{K}{C} + \frac{\mu_{t-1}}{C_{t-1}}\left(\frac{K}{\gamma_K C}[\frac{C}{K} + \gamma_K] - \frac{1}{\gamma_K}\right) = 0 \tag{35}$$

Now consider (28). Plug (29) and (30) in (28):

$$-\left(\gamma_K - \beta(1-\delta_k) + A\beta(1-\alpha)\left(\frac{g_{t+1}}{K_{t+1}}\right)^{\alpha}\right)\frac{\theta}{E_{t+1}} + \frac{\mu_t\beta}{C_{t+1}}[\frac{C_{t+1} + K_{t+2}}{K_{t+1}^2}] - \mu_{t-1}\frac{1}{C_t K_t} = 0$$

Multiply by K_{t+1} and consider the balanced growth path:

$$-\left(\gamma_K - \beta(1-\delta_k) + A\beta(1-\alpha)X^{\alpha}\right)\right)\theta\frac{K}{E} + \frac{\mu_t\beta}{\gamma_K C_t}[\frac{C}{K} + \gamma_K] - \mu_{t-1}\frac{\gamma_K}{\gamma_K C_{t-1}} = 0$$

Rewrite it:

$$-\left(\gamma_K - \beta(1-\delta_k) + A\beta(1-\alpha)X^\alpha\right)\theta\frac{K}{E} + \frac{\mu_t}{C_t}\frac{\beta}{\gamma_K}[\frac{C}{K} + \gamma_K] - \frac{\mu_{t-1}}{C_{t-1}} = 0 \tag{36}$$

(35) and (36) are difference equations for $\frac{\mu}{C}$. They have to be satisfied at the same time. Hence, this condition can be used to find X. The X that satisfies both (35) and (36) is given by:

$$\frac{\frac{(1-\theta)K}{C} - \frac{\theta K}{E}}{\frac{K}{C}} = \beta\left([1-\delta_g + A\alpha X^{\alpha-1}] - [1-\delta_k + A(1-\alpha)X^\alpha]\right)\theta\frac{K}{E} \tag{37}$$

Once $\frac{C}{K}$ and $\frac{E}{K}$ are substituted from equations (33) and (34), one can solve for X using (37). Now consider the Euler equation from the consumer's problem:

$$\frac{C_{t+1}}{C_t} = \beta[(1-\tau_{t+1})r_{t+1} + 1 - \delta_k]$$

From the government's problem:

$$\frac{C_{t+1}}{C_t} = \beta[1-\delta_g + A\alpha X^{\alpha-1}]$$

Equating the two:

$$\tau = 1 - \frac{1-\delta_g + A\alpha X^{\alpha-1} - (1-\delta_k)}{AX^\alpha}$$

Then the balanced growth path is characterized by the set of equations provided in Proposition 4.

Proof of Proposition 6

(a) With full depreciation: $i_g = g_{t+1}$. Moreover, following Proposition 4, on the balanced growth path: $g_{t+1} = \gamma g_t$. Then:

$$\frac{i_g}{Y} = \frac{\gamma g}{Y}$$

Using $\gamma = \beta A\alpha(\frac{g}{K})^{\alpha-1}$ from Proposition 4 and $Y = AK(\frac{g}{K})^\alpha$ from equation (15):

$$\frac{i_g}{Y} = \frac{\beta A\alpha(\frac{g}{K})^{\alpha-1}g}{AK(\frac{g}{K})^\alpha} = \beta\alpha \tag{38}$$

(b) From equation (15):

$$\frac{K}{Y} = \frac{1}{A(\frac{g}{K})^\alpha}$$

From Proposition 4:

$$\frac{E}{Y} = \frac{E}{K}\frac{K}{Y} = [A(\frac{g}{K})^\alpha - (\frac{1}{\beta} + \frac{g}{K})\beta A\alpha(\frac{g}{K})^{\alpha-1}]\frac{K}{Y}$$

Plugging in for K/Y:

$$\frac{E}{Y} = \frac{E}{K}\frac{K}{Y} = [A(\frac{g}{K})^{\alpha} - (\frac{1}{\beta} + \frac{g}{K})\beta A\alpha(\frac{g}{K})^{\alpha-1}]\frac{1}{A(\frac{g}{K})^{\alpha}}$$

Simplifies to:

$$\frac{E}{Y} = 1 - (\frac{1}{\beta} + \frac{g}{K})\beta\alpha\frac{1}{g/K}$$

Plugging in $\frac{g}{K} = \frac{\alpha}{(1-\theta)(1-\beta)+\beta(1-\alpha)}$ from equation (12), and simplifying:

$$\frac{E}{Y} = \theta(1-\beta)$$

Using equation (38):

$$\frac{i_g + E}{Y} = \beta\alpha + \theta(1-\beta)$$

(c) From Proposition 4, with full depreciation:

$$\tau = 1 - \frac{\alpha}{g/K}$$

Plugging in for $\frac{g}{K}$ from equation (12) and simplifying:

$$\tau = 1 - \frac{\alpha}{\frac{\alpha}{(1-\theta)(1-\beta)+\beta(1-\alpha)}} = \theta(1-\beta) + \beta\alpha$$

Proof of Proposition 7

(a) With full depreciation: $i_k = K_{t+1}$. Moreover, following Proposition 4, on the balanced growth path: $K_{t+1} = \gamma K_t$. Then:

$$\frac{i_k}{Y} = \frac{\gamma K}{Y}$$

Using $\gamma = \beta A\alpha(\frac{g}{K})^{\alpha-1}$ from Proposition 4 and $Y = AK(\frac{g}{K})^{\alpha}$ from equation (15):

$$\frac{i_k}{Y} = \frac{\beta A\alpha(\frac{g}{K})^{\alpha-1}K}{AK(\frac{g}{K})^{\alpha}} = \frac{\beta\alpha}{g/K}$$

Plugging in $\frac{g}{K}$ from equation (12), and simplifying:

$$\frac{i_k}{Y} = \frac{\beta\alpha}{\frac{\alpha}{(1-\theta)(1-\beta)+\beta(1-\alpha)}} = \beta[(1-\theta)(1-\beta) + \beta(1-\alpha)]$$

(b) Proof provided in the main text.

Appendix C - Data

List of countries included in the sample

Argentina, Australia, Austria, Azerbaijan, Belgium, Bolivia, Brazil, Bulgaria, Cameroon, Canada, Chile, China, Colombia, Costa Rica, Cote d'Ivoire, Denmark, Ecuador, Egypt, El Salvador, Estonia, Ethiopia, Finland, France, Germany, Ghana, Greece, Iceland, India, Indonesia, Ireland, Italy, Japan, Jordan, Kazakhstan, Kenya, Lithuania, Luxembourg, Malawi, Malaysia, Mauritius, Mexico, Morocco, Netherlands, New Zealand, Nigeria, Norway, Peru, Philippines, Poland, South Africa, South Korea, Spain, Sweden, Switzerland, Thailand, Tunisia, Turkey, Uganda, UK, USA, Uzbekistan, Venezuela, Zambia, Zimbabwe.

Advanced countries included in the sample

Australia, Austria, Belgium, Canada, Denmark, Estonia, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, South Korea, Spain, Sweden, Switzerland, UK, and USA.

Least corrupt countries included in the sample

Canada, Denmark, Finland, Iceland, Luxembourg, Netherlands, New Zealand, Norway, Sweden, Switzerland, and UK.

Most corrupt countries included in the sample

Azerbaijan, Bolivia, Cameroon, Côte d'Ivoire, Ecuador, Indonesia, Kenya, Nigeria, Uganda, Uzbekistan, and Venezuela.

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