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The Quality of Public Investment

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Abstract

This paper develops a growth model with specialized goods where inefficient and corrupt bureaucracies interact with the provision of public investment services in affecting the productivity of private capital, specialization, and growth. The model provides potential explanations for the contradictory empirical results on the effects of public investment found in the literature as well as for the role of the quality of public infrastructure investment in creating a gap between rich and poor countries. From a policy perspective, the paper suggests that the link between public investment and growth depends critically on the quality and efficiency of public capital.

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I. INTRODUCTION

Conventional wisdom suggests that public infrastructure capital in the form of power, transport, and telecommunications, allows access to additional productive opportunities and enhances growth. At the same time, differences in endowments of such capital are often viewed as accounting for the large output and productivity differences observed across countries. Since the seminal work by Aschauer (1989), a large number of empirical studies have found support for a positive and significant contribution of public investment to the level and growth of aggregate output. The magnitudes of these contributions, however, vary considerably from one study to another because of differences in econometric methodology employed, measurement of physical capital, and the level of data aggregation (see Straub, 2007, 2008; Romp and de Haan, 2007, and references therein). Studies at the industry, regional, and sectoral level find much lower estimates for the elasticity of public infrastructure capital to growth as compared to macro-level studies.

In general, studies that use public investment flows (or their cumulative assets) tend to find ambiguous and negligible growth effects of public infrastructure investment, particularly for low-income countries (Easterly and Rebelo, 1993; Pritchett, 2000).The likely reason for this is that investment spending may be a poor proxy for the accumulation of productive assets.[1] The role of poor infrastructure and ineffective use of public capital has been cited as a determinant of the differential growth performance across countries and in productive investments by firms (see for example Hulten 1996; Calderon and Serven 2007; Reinnikka and Svensson 2002).[2]

It is also well known that many low-income countries are characterized by weak institutions. Several recent empirical studies suggest that deficiencies in public capital provision and its growth effects may be particularly linked to the existence of inefficient or corrupt bureaucracies (Esfahani and Ramirez, 2003; Dal Bo and Rossi, 2007).[3] This can also be seen in Figure 1, which shows a clear negative correlation between an aggregate index of infrastructure quality and a country-wide index of the control of corruption.

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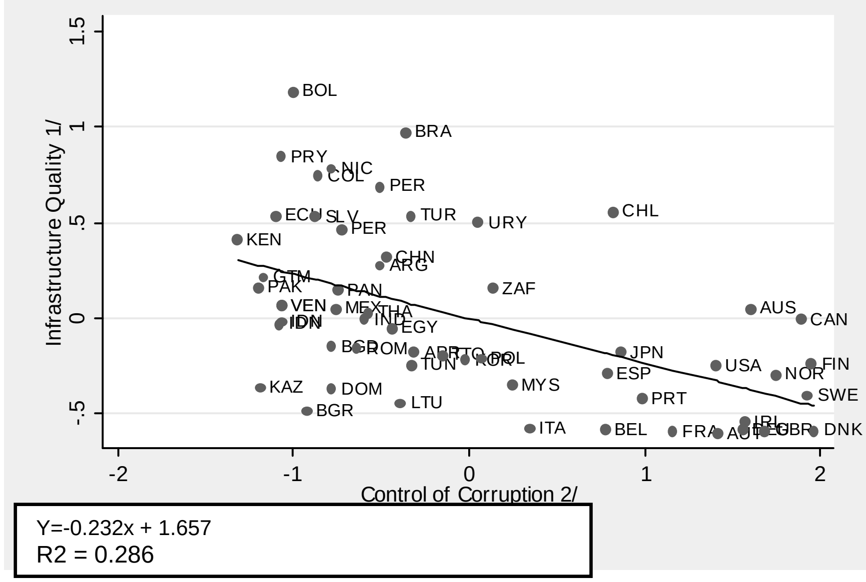
[1] In an extensive survey of the literature, Straub (2007) finds that empirical studies that use physical indicators of infrastructure generally find a significant positive output or growth contribution of infrastructure. However, less than half of the empirical studies using expenditure-based infrastructure measures find significant positive growth effects.

[2] Hulten (1996) finds that differences in the effective use of infrastructure resources explain one-quarter of the growth differential between Africa and East Asia, and more than 40 percent of the growth differential between low-and high-growth countries. Calderon and Serven (2008) find evidence that an improved quality of infrastructure services can have a positive effect on long-run growth in Sub-Saharan African. Using firm-level data for Uganda, Reinnikka and Svensson (2002) show that poor provision of public infrastructure services significantly reduces investment in the productive capacity of firms.

[3] Esfahani and Ramirez (2003) show that the growth effects of infrastructure depend upon the strength of a country’s institutions, such as contract enforcement and bureaucratic efficiency. Dal Bo and Rossi (2007) find that greater corruption is significantly associated with lower efficiency of electricity distribution.

Figure 1. Infrastructure Quality vs. Control of Corruption



1/ The index of Infrastructure Quality is compiled by Calderon and Serven (2004) by applying a principal component analysis to three indicators of quality in the services of telecommunications Higher values denote poor infrastructure quality.
2/ Control of Corruption indicator is from Kaufmann et al. (2008) and measures the exercise of public power for private gain, including both petty and grand corruption and state capture. Higher values denote better control of corruption.

This paper presents a simple framework that reconciles the contradictory empirical results mentioned above, as well as for the role of the quality of public infrastructure investment in creating a gap between rich and poor countries. We develop a model in which inefficient and corrupt bureaucracies interact with the provision of public investment services in their effect on the productivity of private capital and growth.

In the model, public investment reduces costs of producing intermediate inputs, thereby fostering specialization. But in the presence of corruption, the extent of specialization and private capital investment depend on the availability of complementary public oversight and enforcement. We show that government oversight of bureaucrats is less effective when corruption is entrenched. Lower oversight, and the resulting higher corruption, reduces the effectiveness of government spending and leads to much lower growth than would be the case in the absence of specialization.[4] This feature of our model provides a potential explanation for reconciling the varying estimates of the elasticity of public infrastructure capital to growth found in macro-level studies as well as the smaller magnitudes found in sectoral and micro-studies.

[4] This is consistent with Duggal et al (2007) who show that public capital, through a combination of its direct productivity effect, as well as its indirect effect through efficiency-enhancing externalities, has the potential to generate increasing returns to scale at the aggregate level.

A key feature of our framework is that the extent of corruption in an economy, the quality of public infrastructure, and growth, are all jointly determined. In particular, this implies that public investment is more efficient in developed relative to poorer countries. We also show that the quality of public investment can account for significant income gaps between rich and poor countries in the presence of endogenous specialization. Moreover, given that the quality of monitoring and bureaucratic oversight play a key role in the realization of investment returns in the model, our analysis has important policy implications. It implies that any scaling-up of public investment needs to be accompanied by improvements in the mechanisms for screening, monitoring, and oversight of investment decisions.

To shed light on the above issues, we extend Romer's (1987) endogenous growth model, which relies on specialization in production, by introducing infrastructure as a publicly provided good that raises the productivity of intermediate inputs as in Glomm and Ravikumar (1994). Because final output is increasing in the number of intermediate inputs, public infrastructure fosters economic growth by promoting specialization. However, as in Sarte (2001), the precise growth effects of public investment and its efficiency are linked to an agency problem between the government and its bureaucracy. Public infrastructure is provided by bureaucrats, but bureaucratic malfeasance lowers the quality of public expenditures. Moreover, bureaucratic decision making entails strategic interactions that give rise to multiple, frequency-dependent equilibria associated with different incidences of corruption, quality of public infrastructure, and growth.[5]

The paper proceeds as follows. Section II specifies the basic model and Section III examines the properties of equilibrium. In section IV, we discuss the implications of our model. We conclude in Section V.

II. The Environment

We start by constructing a simple general equilibrium model of corruption and public capital. Time is discrete and indexed by $t = 0, \ldots, \infty$. There is a constant population of two-period lived agents belonging to overlapping generations of families. Individuals work for a unit time in youth and consume only in old age.[6] The measure of agents born every period is unity.

Households either work for firms in the production of output or work for the government as bureaucrats, overseeing public works projects. This is decided by a lottery before households enter the labor market. At any point in time a measure $m < 1$ of public works projects are in

[5] These strategic interactions have been incorporated into several models of corruption (see Andvig and Moene, 1990). Mauro (2004) relies on strategic complementarities similar to the ones considered in our paper to explain the persistence of corruption and low growth in some countries. However, he does not examine the implications of the quality of public investment spending and bureaucratic oversight for specialization and capital accumulation.

[6] The assumption that all first period income is saved is made for convenience. Non-trivial saving decisions only affect steady-state income levels, but not income ratios or the effect of public investment on output.

operation. Each project $j \in [0, m]$ is managed by a single official so that m also denotes the proportion of the workforce engaged in the public sector. Production of output is undertaken by firms of which there is a continuum of unit mass. Firms hire labor and rent capital from households.

Production

Final Goods Producers

The final consumption good is produced in a competitive sector using a variety of intermediate goods x. The range of intermediate goods at t, n_t, is endogenous. For a given n_t, the technology that combines intermediate goods into final output is

$$Y_t = \left[\int_0^{n_t} x_{it}^{1-\sigma} di \right]^{1/(1-\sigma)} \tag{1}$$

where $\sigma \in [0,1]$ is the inverse of the elasticity of substitution between intermediate goods.[7] In a symmetric equilibrium, $x_{it} = x_t \;\; \forall t$, so that

$$Y_t = n_t^{1/(1-\sigma)} x_t \tag{2}$$

Consider now the input demands by a final goods producer. A perfectly competitive firm hires $\{x_{it}\}_{i=0}^{n_t}$ at prices $\{p_{it}\}_{i=0}^{n_t}$ to maximize profits

$$\Pi_t = \left[\int_0^{n_t} x_{it}^{1-\sigma} di \right]^{1/(1-\sigma)} - \int_0^{n_t} p_{it} x_{it} di$$

where the price of the final good is normalized to 1. The first-order conditions for each intermediate good imply that the demand for the *i*-th intermediate good is

$$x_{it} = \left(\frac{1}{p_{it}} \right)^{1/\sigma} Y_t. \tag{3}$$

[7] The intermediate goods can be interpreted as the many specialized goods that are used in multiple stages of production. Output of the final good is increasing in the range of intermediate goods with an elasticity greater than one.

Intermediate Goods Producers

The intermediate goods sector is monopolistically competitive. Operating a particular intermediate goods producing firm requires a fixed cost of φ units of the final good every period. Production of each intermediate good utilizes a technology that is CRS in the firm's private inputs, capital (k) and labor (l):

$$x_{it} = Ag_t^{\theta} k_{it}^{\alpha} l_{it}^{1-\alpha} \tag{4}$$

subject to public capital externalities. The firm's effective productivity Ag_t^{θ} depends on the technology-specific term A and the aggregate public capital stock adjusted for the scale of the economy, that is, $g_t = G_t / Y_t$. In this we follow Glomm and Ravikumar (1994) to take into account congestion externalities.[8]

An intermediate goods firm hires labor at a wage rate w and rents capital at the rental rate r to maximize operating profits

$$\Pi_i = p_i x_i - \left(w l_i + r k_i \right)$$

subject to (3) and (4). The first–order conditions associated with l_i and k_i are

$$\begin{aligned} (1-\sigma)(1-\alpha)\frac{p_i x_i}{l_i} &= w \\ (1-\sigma)\alpha \frac{p_i x_i}{k_i} &= r \end{aligned} \tag{5}$$

Substituting the optimal input cost $wl_i^* + rk_i^* = (1-\sigma)\, p_i x_i$ gives optimal operating profits

$$\Pi_i^* = \sigma\, p_i x_i . \tag{6}$$

Given free entry into the *i*–th sector, these profits are dissipated by entry costs in equilibrium:

$$\sigma\, p_i x_i = \varphi \text{ for all } i. \tag{7}$$

From (2) and (3) we get

$$p_{it} = n_t^{\sigma/(1-\sigma)} \text{ for all } i. \tag{8}$$

From (7) and (8) it follows that

$$x_{it} = \left(\frac{\varphi}{\sigma} \right) n_t^{-\sigma/(1-\sigma)} \tag{9}$$

[8] That is public goods are not pure private goods being subject to some rivalry as in Barro (1990).

and using this in (3),

$$Y_t = \left(\frac{\varphi}{\sigma}\right) n_t. \tag{10}$$

In a symmetric equilibrium,

$$l_{it} = \frac{L_t}{n_t} = \frac{1-m}{n_t}, \quad k_{it} = \frac{K_t}{n_t} \text{ for all } i$$

so that

$$x_{it} = A(1-m)^{1-\alpha}\, \hat{g}_t^{\theta} K_t^{\alpha} / n_t. \tag{11}$$

Finally (5) and (7) establish that wages are proportional to the range of intermediate goods

$$w_t = \lambda n_t \tag{12}$$

where $\lambda \equiv [(1-\sigma)(1-\alpha)\varphi]/[\sigma(1-m)]$.

The Government

A benevolent government hires bureaucrats to provide public investment that facilitates private production. Specifically, it hires bureaucrats to oversee the construction and management of public works projects. A bureaucrat is offered the market wage w. But, we allow for the possibility of corruption which allows the bureaucrat to earn more by diverting part of the public funds he manages. As in Blackburn et al. (2005), a bureaucrat who is willing to accept a salary lower than w is viewed as expecting to receive compensation through malfeasance and can be immediately identified as being corrupt. A bureaucrat if caught is fined by an amount equal to his salary (i.e., he is dismissed without pay). His appropriated funds are also seized but these are dissipated in legal procedures. As a result, the government can minimize its labor costs while ensuring bureaucratic participation by setting the salaries of all bureaucrats equal to the wage paid to households.[9] Under such circumstances, the government can investigate the behavior of bureaucrats through a costly and imprecise monitoring technology described below.

The government runs a balanced budget. A fraction μ of tax revenues T_t every period goes toward public capital projects with the remaining $1-\mu$ devoted toward monitoring and auditing corrupt bureaucrats. Since bureaucrats are paid w_t and m projects are financed every period, public capital outlays are

$$\mu T_t - m w_t$$

[9] This can be interpreted as an allocation of talent condition: the government can induce potential bureaucrats to take up public office only by paying them what they could earn elsewhere (see Acemoglu and Verdier, 1998).

with each project getting

$$q_t^j = \frac{\mu}{m} T_t - w_t, \quad j \in [0, m] \tag{13}$$

Allowing for leakages due to corruption or inefficiency, each project yields a quality-adjusted public capital of

$$G_t^j = \varepsilon_t q_t^j \tag{14}$$

where $\varepsilon \in [0,1]$. Since all bureaucrats face the same problem (see below), the efficiency index is same across various public works projects. The aggregate public capital stock is then

$$G_t = \int_0^m G_t^j dj = \varepsilon_t q_t \tag{15}$$

where $q_t \equiv \int_0^m q_t^j dj = \mu T_t - m w_t$.

Taxes are levied on labor income of both workers and bureaucrats. Bureaucrats pay taxes on their legitimate labor earnings but not on misappropriated government funds because they hide such income to avoid easy detection.[10] Hence,

$$T_t = \tau w_t = \lambda \tau n_t . \tag{16}$$

where the last equality follows from equation (12). Combining (13), (14), and (16) we get

$$G_t^j = \varepsilon_t \left(\frac{\mu\tau}{m} - 1 \right) w_t = \lambda \left(\frac{\mu\tau}{m} - 1 \right) \varepsilon_t n_t \tag{17}$$

and

$$g_t = \frac{G_t}{Y_t} = \zeta \varepsilon_t \tag{18}$$

where $\zeta \equiv \lambda \sigma (\mu\tau - m) / \varphi$.

Households

Since all households consume in the second period of life, they save their entire first period post-tax income. Workers earn only wage income so that their savings is given by

$$s_t^w = (1 - \tau) w_t . \tag{19}$$

[10] Bureaucrats are also responsible for tax collection which could be subject to bribery and tax evasion. But this does not arise in our model as all households have the same income and are subject to the same tax liability.

Bureaucrats

Consider now the behavior of a typical bureaucrat. Given q funds at his disposal, the bureaucrat managing any project can invest the full amount or a portion $(1-v)q$ of it, where $v \in [0,1]$. If he does the latter, he pockets vq. Public works projects are either of high-quality or low-quality. Quality is observed only at the end of every period. The tradeoff the bureaucrat faces is that appropriating more funds results in a lower expected quality of public capital, and hence, a greater threat of detection. In general, in the absence of effective oversight and control, bureaucratic corruption could manifest in several ways: funds earmarked for public infrastructure projects could end up in private pockets of corrupt bureaucrats, government revenues for public investment be diverted for personal use or to where bribes are easiest to collect, implying a bias in the composition of public spending toward low-productivity projects, at the expense of value-enhancing investments.

In particular, for an investment of $(1-v)q$, the quality-adjusted public capital is

$$g = \begin{cases} \delta_H q, & \text{with prob. } 1-\pi(v) \\ \delta_L q, & \text{with prob. } \pi(v) \end{cases} \tag{20}$$

where $\pi:[0,1]]\times[\pi_0,1]$, $\pi_0 \geq 0$, $\pi \in C^2$ with $\pi'(v) > 0$ and $\delta_H > \delta_L$. The expected quality of the project $\delta_H - \pi(v)(\delta_H - \delta_L)$ is decreasing in the level of theft, *v*.

The government uses a simple rule-of-thumb: a project is audited whenever it is of low quality. This means $\pi(v)$ also denotes the bureaucrat's probability of being audited. But not all audits are successful and the success probability is ϕ.[11] An apprehended corrupt bureaucrat is fined an amount at least equal to his salary and his appropriated funds are seized. We also assume that legal expenses required to prosecute the bureaucrat are proportional to funds appropriated, so that the entire amount of appropriated funds (vq) are dissipated. When a bureaucrat is not apprehended, he invests his legitimate and illegitimate earnings in the loanable funds market at the end of *t*. The bureaucrat's expected income at the end of *t* is, therefore, given by

$$\left[1-\phi\pi(v)\right](w+vq)$$

which he maximizes by his choice of $v \in [0,1]$. The associated first order condition in an interior optimum is

$$1-\phi\pi(v) = \phi\pi'(v)\left(\frac{w}{q}+v\right)$$

[11] See Sarte (2001) for a model of bureaucratic oversight and effectiveness of productive government spending.

This implicitly defines the bureaucrat's optimal theft level as

$$v = V\left(\phi, \frac{w}{q}\right)$$

which is decreasing in the probability of being audited successfully and with wage compensative relative to project size.[12] For example, when the probability function takes the linear form, $\pi(v) = \pi_0 + (1-\pi_0)v$, optimal theft

$$v = \frac{1}{2}\left[1 + \frac{1-\phi}{\phi(1-\pi_0)} - \frac{w}{q}\right],$$

is decreasing in both ϕ and w/q.

While a bureaucrat takes the probability of being successfully audited as exogenous to his decisions, it is endogenously determined in the model. We assume that ϕ depends on two factors. It depends negatively on the average level of theft among public officials, denoted by $\overline{v}$. When other bureaucrats engage in large-scale theft of public funds, it becomes harder for auditors to detect and apprehend a particular bureaucrat (see Lui, 1986; and Dabla-Norris and Freeman, 2004).

Secondly, we allow ϕ to be influenced by the quality of law enforcement *e*. Enforcement depends on how much resources are devoted towards it relative to the scale of public works projects that have to be monitored. Recall that $(1-\mu)T$ is allocated for law enforcement every period. Since the scale of public projects is $(\mu T - mw)$, enforcement quality is taken to be

$$e = \frac{(1-\mu)\tau}{\mu\tau - m} \tag{21}$$

for all *t*.

Based on these we specify the probability of a successful audit as

$$\phi_t = \phi(\overline{v}_t, e_t) \tag{22}$$

where $\phi_1 < 0$ and $\phi_2 > 0$. Moreover, we require that $\phi(0, e_t) = 1$ so that in the absence of theft any deviation by a particular bureaucrat is detected for sure if he is audited. One functional form that satisfies these properties is

[12] The former holds as long as $\pi(v)$ is not sharply concave.

$$\phi\left(\bar{v},e\right)=1-\frac{\beta\bar{v}^{\theta}}{e},\quad \theta\geq 1 \tag{23}$$

We can now describe the equilibrium level of corruption. This is illustrated by Figure 2 using the functional forms above to construct the bureaucrat's marginal benefit ($B(v)$) and marginal cost ($C(v)$) from diverting an additional unit of public capital outlays. These marginal benefit and cost curves are given by:

$$B(v)\equiv 1-\left[\pi_0+(1-\pi_0)v\right]\left[\frac{e}{\theta v+e}\right] \text{ and } C(v)\equiv(1-\pi_0)\left[\frac{e}{\theta v+e}\right]\left(\frac{w}{q}+v\right)$$

Since all bureaucrats face identical problems, we impose $\bar{v}=v$ in equilibrium. Equilibrium levels of corruption are given by the points at which net marginal benefit is zero. Two such levels (v_M,v_H) are identified in Figure 2. In addition, zero corruption is also an equilibrium. no corruption line with the horizontal axis. But it can be shown that the intermediate corruption equilibrium is not stable under small deviations. The two feasible corruption equilibria are, therefore $(0,v_H)$.

That multiple equilibrium levels of corruption can occur is not surprising. It is simply another instance of the proliferation of equilibria under strategic complementarity. This complementarity arises from the way a bureaucrat's corruption incentives depend on the actions of other agents. When other bureaucrats are highly corrupt and engage in theft, the probability of being detected is small for a particular bureaucrat and, consequently, his incentives of corruption are high.

III. General Equilibrium

Quality of Public Capital

Given the equilibrium level of corruption/theft $v\in\{0,v_H\}$, we now turn to the general equilibrium analysis. For either of these two levels of *v*, a fraction $1-\pi\left(v\right)$ of projects will be of good quality since there is a continuum of these projects. From (15) the average quality of public investment

$$G_t=\lambda(\mu\tau-m)\left[\delta_H-\pi\left(v\right)(\delta_H-\delta_L)\right]n_t \tag{24}$$

leads to

$$g_t\equiv\frac{G_t}{Y_t}=\gamma\left[\delta_H-\pi\left(v\right)(\delta_H-\delta_L)\right], \tag{25}$$

via equation (10). Here we have defined $\gamma \equiv \lambda\sigma(\mu\tau - m)/\varphi$. Quality-adjusted public capital is higher for lower levels of corruption and takes either of two values $g \in \{g_H, g_L\}$ given by

$$g_H = \gamma\left[\delta_H - \pi_0(\delta_H - \delta_L)\right], \quad g_L = \gamma\left[\delta_H - \{\pi_0 + (1-\pi_0)v_H\}(\delta_H - \delta_L)\right],$$

depending on the corruption equilibrium the economy is in.

In the previous section, we established that it is possible to have multiple equilibria in corruption for a given pair of (w_t, q_t), both of which are determined by k_t in general equilibrium. What is relevant for a bureaucrat's incentives to be corrupt is the ratio w_t / q_t, which depends only on the model's parameters and is time invariant:

$$\frac{w_t}{q_t} = \frac{mw_t}{(\mu\tau - m)w_t} = \frac{m}{\mu\tau - m}.$$

This then makes the theft problem independent of time, and allows us to assume that the economy remains in either of the two corruption equilibrium through time. In other words, quality-adjusted public capital g is time-invariant and, in particular, does not co-evolve with k_t.

To determine equilibrium dynamics, we express the equilibrium range of intermediate goods in terms of the capital stock using (9) and (11)

$$n_t = a\left(g\right)^{\theta(1-\sigma)/(1-2\sigma)} K_t^{\alpha(1-\sigma)/(1-2\sigma)} \tag{26}$$

where $a \equiv \left[\sigma A(1-m)^{1-\alpha} / \varphi\right]^{(1-\sigma)/(1-2\sigma)}$. This allows us to write down a reduced-form aggregate technology

$$Y_t = \left(\frac{\varphi}{\sigma}\right) n_t = \left(\frac{\varphi\sigma}{\sigma}\right)\left(g\right)^{\theta(1-\sigma)/(1-2\sigma)} K_t^{\alpha(1-\sigma)/(1-2\sigma)} \tag{27}$$

One interesting feature of this reduced form relationship is the output elasticity of public investment. Recall that the direct productivity effect of quality-adjusted public investment g on a firm's output is θ. Indirectly though, that productivity effect has a bearing on a firm's decision to enter the market. Productive public investment generates a higher flow of profits in the intermediate goods industry and eases the entry of newer types of goods. It is this specialization effect that generates a gap between the micro and macro impacts of public capital.

The combined effect of public capital is captured by the effective elasticity $\theta(1-\sigma)/(1-2\sigma)$ which exceeds θ since $\sigma \geq 0$. The effective elasticity is also increasing in σ. Since the elasticity of substitution across intermediate goods is $1/\sigma$, this implies that the effect of market entry is larger the more complementary are various intermediate goods in production.

Asset Market Clearing

In equilibrium, a fraction $\phi(v;e)\pi(v)$ of bureaucrats are apprehended and earn zero net income. Those not apprehended invest their earnings, both legal and illegal, in the loanable funds market. Total savings for bureaucrats is then simply the post-tax income of non-apprehended bureaucrats

$$\begin{aligned} z_t^B &= (1-\phi\pi)\left[(1-\tau)w_t + vq_t\right] \\ &= \frac{1}{m}(1-\phi\pi)\left[(1-\tau)m + v(\mu\tau - m)\right]w_t \end{aligned}$$

where the last equality follows from (13).

Aggregate savings comprising of the savings of workers and bureaucrats is hence

$$z_t = \left[(1-\phi\pi)\left\{(1-\tau)m + v(\mu\tau - m)\right\} + (1-\tau)(1-m)\right]w_t \equiv \Gamma(v)w_t$$

Note here that corruption has an effect on the flow of savings. It increases bureaucrats' illegal earnings flowing through the loanable funds market. At the same time, it has an effect on the equilibrium probability that a bureaucrat is apprehended. It can be shown that this probability is decreasing in the level of theft in the high corruption equilibrium, and increasing in the low corruption one.

Finally from (12) and (26), we get

$$w_t = \lambda a\left(g\right)^{\theta(1-\sigma)/(1-2\sigma)} K_t^{\alpha(1-\sigma)/(1-2\sigma)}$$

which allows us to write down the asset market clearing condition as

$$K_{t+1} = \lambda a\Gamma(v)\left(g\right)^{\theta(1-\sigma)/(1-2\sigma)} K_t^{\alpha(1-\sigma)/(1-2\sigma)}. \tag{28}$$

Given an initial capital stock $K_0 > 0$ owned by the initial old, equation (28) completely characterizes the dynamic equilibria of this economy. A unique asymptotically stable steady-state capital stock exists as long as the exponent on K_t on the right hand side is less than one, that is, as long as $\alpha(1-\sigma)/(1-2\sigma) < 1$, or equivalently,

$$\sigma < \frac{1-\alpha}{2-\alpha}$$

the right-hand side of which does not exceed 1/2. We shall maintain this parametric restriction and note that since it implies $\sigma < 1/2$ it also ensures that the exponent on g_t in equation (29) is positive.
The steady-state capital stock is given by

$$\bar{K} = \left[\lambda a \Gamma(v)\right]^{(1-2\sigma)/\{1-2\sigma-\alpha(1-\sigma)\}} \left(g\right)^{\theta(1-\sigma)/\{1-2\sigma-\alpha(1-\sigma)\}}$$

which implies the following expression for steady-state output per worker

$$\bar{y} = \mathrm{M}(v)\left(g\right)^{\frac{\theta(1-\sigma)}{1-2\sigma-\alpha(1-\sigma)}} \tag{29}$$

where we have defined $\mathrm{M}(v) \equiv \dfrac{\varphi}{\sigma(1-m)^{\alpha}}\left[\lambda a \Gamma(v)\right]^{\alpha(1-2\sigma)/\{1-2\sigma-\alpha(1-\sigma)\}}$.

Corruption enters this expression via g and $\Gamma(v)$. It lowers the quality of public investment, discourages specialization and thereby lowers the steady-state output per worker. Through the term $\Gamma(v)$, it also affects the flow of bureaucrats' savings. But this effect is ambiguous. Recall that

$$\Gamma(v) \equiv \left[1-\phi(v)\pi(v)\right]\left[\left\{(1-\tau)m + v(\mu\tau - m)\right\} + (1-\tau)(1-m)\right].$$

One the one hand, higher degrees of corruption mean bureaucrats appropriate more of public investment outlays which, through the loanable funds market, raises investment. On the other hand, higher corruption also means more of corrupt activities are detected (the $\pi(v)\phi(v)$ term) which tends to negatively affect capital accumulation. It is debatable then what the net effect is and whether it will be quantitatively significant. Since our focus is on the provision of public investment and its quality, we ignore this effect.

IV. Discussion

A. Micro versus Macro Evidence

There is a wealth of evidence to suggest that public infrastructure contributes significantly to growth of output, reduction in costs, and increase in profitability (see Straub, 2007, 2008). Macro-estimates of the output elasticity of public capital tend to be larger, often substantially so, than the few micro-estimates that are available. Early estimates (Ashauer, 1989, and others) based on aggregate production function analyses report output elasticities of public capital ranging from 0.31 to 0.54. But more recent evidence using more sophisticated empirical approaches points to a lower elasticity of about 0.20 to 0.30 at the national level and possibly lower at the regional level.

Estimates based on state and metropolitan level data suggest elasticities of approximately 0.06 to 0.20 (Straub, 2008; Romp and de Haan, 2007). Studies at the industry level are generally confined to the manufacturing sector or a specific subset of this sector. Here again, many studies find significant productive effects of public capital. For instance, Pineda and Rodriguez (2006) use data for Venezuela to estimate the effect of public infrastructure investment on the productivity of Venezuelan manufacturing firms. Their estimates indicate that a 1 percent increase in the allocation to public expenditures generates an increase in productivity of the manufacturing sector of between 0.2 and 0.35.

In this paper, public capital has been modeled as directly contributing to a firm's productivity. The model offers a simple intuitive reconciliation of relatively lower micro estimates of this productivity effect with relatively higher macro estimates. To frame our discussion it is instructive to start with a simpler specification of public capital than in the model. The paradigm adopted by a large literature on public investment and economic growth (for example, Barro, 1990; Glomm and Ravikumar, 1994, 1999; Fisher and Turnovsky, 1998, among others) does not allow for firm entry, specifying a direct productivity effect on aggregate output.[13] In terms of our model, this is tantamount to fixing the range of intermediate goods and starting with a reduced-form aggregate technology based on equations (2) and (4):

$$Y_t = n^{1/(1-\sigma)} x_t = Bg^{\theta} K_t^{\alpha} \tag{30}$$

where $B \equiv An.^{\sigma/(1-\sigma)}$ A quick comparison with our aggregate technology (equation (27)) shows that public capital has a larger impact under endogenous specialization. This is, of course, not surprising but it does provide a rationale for different estimates in the micro- and macro-empirical literature.

Even if the direct productivity effect of public capital is relatively small, as micro-estimates find, the macro-effects can be magnified via the effect of quality-adjusted public investment on intermediate goods specialization. The more complementary intermediate goods are, the greater this magnification effect. For instance, Hulten et al. (2006) using data for Indian states, find a substantial externality effect from the states' infrastructure to manufacturing productivity. For the period 1972 to 1992, they find that the growth of road and electricity-generating capacity accounted for nearly half the growth of the productivity residual of India's registered manufacturing.

From equation (30) above, the macroeconomic elasticity of aggregate output with respect to quality-adjusted public investment is $\theta(1-\sigma)/(1-2\sigma)$. Table 1 reports this elasticity for various combinations of the elasticity of firm output with respect to public capital (θ) and complementarity of intermediate goods (σ). While we have some evidence on what reasonable values of θ are, empirical evidence for σ is scant. The sole exception we are

[13] Few of these papers explicitly consider corruption or inefficiencies in public investment provision.

aware of is Acemoglu and Ventura (2002), who report an estimate of 2.6 for the elasticity of substitution among intermediate goods. This implies a point elasticity of $\sigma = 1/2.6 = 0.38$.

Table 1 demonstrates that public capital can be quite productive in the presence of significant complementarities across intermediate goods. Even a conservative estimate of the micro-elasticity $\theta = 0.10$ implies a macro elasticity of about 0.30, in line with some of the macroeconomic studies on the productivity of public capital.

Table 1. Effective Output Elasticity of Public Capital

	$\sigma = 0.1$	$\sigma = 0.2$	$\sigma = 0.3$	$\sigma = 0.4$
$\theta = 0.05$	0.06	0.07	0.09	0.15
$\theta = 0.10$	0.11	0.13	0.18	0.3
$\theta = 0.15$	0.17	0.2	0.26	0.45
$\theta = 0.20$	0.23	0.27	0.35	0.6

B. Accounting for Income Gaps

The distinction of micro- and macro-effects of public capital can consequences for income gaps. For example, embedding the simpler technology of equation (30) in an OLG economy similar to ours leads to a steady-state output per worker of

$$\bar{y} = \tilde{B}(g)^{\theta/(1-\alpha)} \tag{31}$$

where the constant $\tilde{B}$ depends on B and other model-specific parameters. Compare again this equation to (29): the steady-state elasticity of public capital on income levels is higher in (29) as long as $\sigma > 0$. What this implies is that differences in the *quality* of public investment yield a larger steady-state output gap when specialization is endogenous.

We examine this issue more closely. Recall from our discussion above that two equilibrium levels of corruption in public capital provision are possible. Which equilibrium obtains depends upon expectations about the average level of corruption in the economy. In one of the equilibria, the level of corruption and inefficiency is zero and all public capital outlays are converted into productive capital. Positive theft levels in the other equilibrium imply leakages in public investment provision and a lower quality of the public capital stock. Suppose we interpret these two corruption and public capital equilibria as pertaining to rich (*R*) and poor (*P*) countries. That is, suppose $g^R \equiv g_H$, $g^P \equiv g_L$. Moreover, suppose that the average rich and poor countries differ only in corruption levels and, hence, in the quality of their public investment. The question we ask is to what extent such quality differences account for observed income gaps. From (31) above

$$\frac{\overline{y}^R}{\overline{y}^P}=\left[\frac{g^R}{g^P}\right]^{\frac{\theta(1-\sigma)}{1-2\sigma-\alpha(1-\sigma)}} \tag{32}$$

The difficulty in working with this expression is that we have no way of quantitatively pinning down corruption levels in the two countries. One way around this is to look at estimates of public capital quality or efficiency and impute them directly into equation (32) above with the caveat that public capital quality can differ for reasons besides corruption (for instance, technology gaps and other institutional failures).

Two studies notably estimate the quality of public capital across countries. Hulten (1996) defines the relationship between effective and actual public capital stocks as

$$g_e=\varepsilon g$$

where ε is a measure of the average level of public capital effectiveness. His dataset covers middle- and low-income countries over the period 1970-1990. The difference between public capital as a share of GDP in the top-third richest middle-income countries and bottom third is 12.4 percent versus 8.6 percent for similar categories in low income countries. The average efficiency index for top third countries is 0.65 as opposed to 0.45 for low income countries. This gives us a ratio of quality adjusted public capital in rich versus poor countries of about 1.45.

Calderon and Serven (2004) compile data on infrastructure quality stocks across both low-income and high-income countries. Using their dataset, we can again compute the average efficiency index of infrastructure quality stocks in rich and poor countries. This gives us a ratio of quality adjusted capital stock of around 3.3 percent (see Table 2).

Table 2. Ratio of Quality-Adjusted Public Capital

	Average Efficiency Index (High = better quality)		g^R/g^P
	Rich	*Poor*	
Hulten (1996)[1/]	0.65	0.45	1.45
Calderon and Sevren (2004)[2/]	-0.274	-0.899	3.28

[1] Information on infrastructure effectiveness sorted by quartiles for 46 low and middle-income countries, inputting values of 1 for top quartile and 0.25 to bottom quartile, and averaged for each infrastructure sector.
[2] Includes 39 rich and low income (excluding upper middle-income) countries. Index of infrastructure quality (logs) based on first principal component of the following normalized variables: waiting years for main lines, electricity

Assuming a range for the quality adjusted public capital of 1.5 to 3 and $\alpha = 0.3$, we can obtain steady-state predictions for output gaps between rich and poor countries for different values of σ and θ. As can be seen from Table 3, small differences in the quality adjusted public investment can result in a large dispersion in steady-state output gaps between rich and poor countries for different values of intermediate goods complementarity (σ) and the direct productivity effect of public capital (θ).

Table 3. Steady-State Predictions for Output Gaps

g^R / g^P	$\bar{y}^R / \bar{y}^P$		
	$\sigma = 0.10$	$\sigma = 0.25$	$\sigma = 0.40$
		$\theta = 0.05$	
1.5	1.04	1.06	1.84
2	1.06	1.10	2.83
3	1.10	1.16	5.20
		$\theta = 0.10$	
1.5	1.07	1.12	3.38
2	1.12	1.21	8.00
3	1.21	1.35	27.00
		$\theta = 0.15$	
1.5	1.11	1.18	6.20
2	1.19	1.33	22.63
3	1.32	1.57	140.30

Moreover, Table 3 shows that differences in the quality of public investment yield a larger steady-state output gap when specialization is endogenous. This suggests that the quality of public capital potentially has significant explanatory power in accounting for income gaps across rich and poor countries.

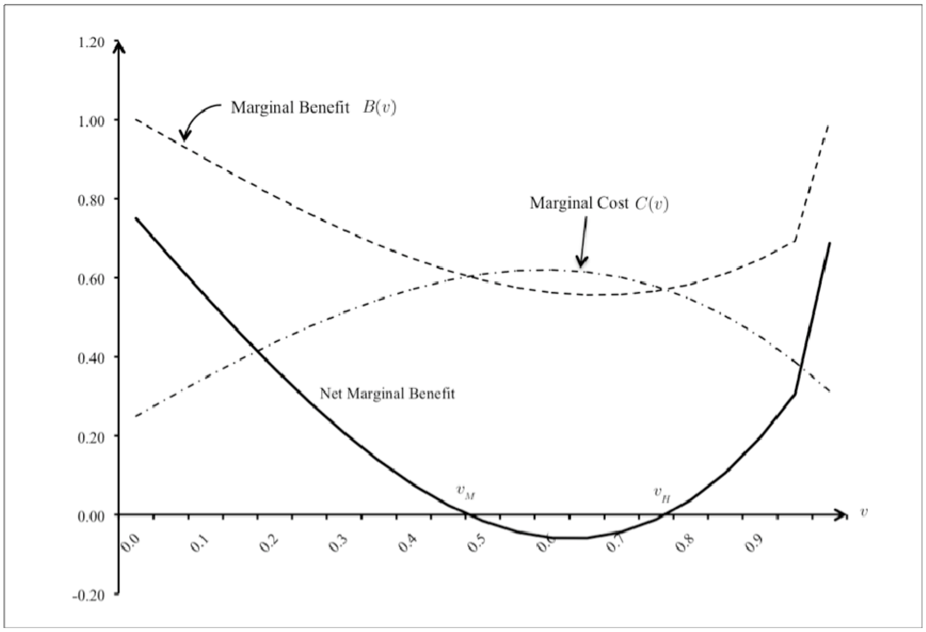
V. Conclusion

In this paper we present a growth model with specialization where the impact of public capital investment on growth depends on the availability of complementary public oversight and enforcement. Many low-income countries are characterized by weak public sector institutions. To the extent that these weaknesses lower the productivity and efficiency of public investment, the end result is a lower rate of return to private investment, less specialization, and hence, lower growth.

This simple framework provides potential explanations for several issues raised in the empirical literature. In particular, we show that the varying estimates of the elasticity of public capital with respect to growth in the macro literature can be explained by inefficiencies in the provision of public investment and the lack of appropriate oversight. We also show that multiple corruption equilibria, rather than technology differences, can account for the observed differences in the quality of public capital across rich and poor countries. Finally we demonstrate that the quality of public investment has the potential to account for a significant portion of cross country income gaps.

From a policy perspective, our analysis suggests that public investment, by fostering specialization and enhancing the productivity of private capital, can have significant direct and indirect growth-enhancing effects. However, the link between investment and development outcomes depends critically on the quality and efficiency of public capital. This highlights the importance of going beyond discussions of spending levels and addressing issues of the broad institutional framework underpinning the provision of investment. In particular, given the interplay between bureaucratic oversight and infrastructure outlays presented in our model, our analysis suggests that simply increasing public spending on infrastructure can be highly inefficient. Therefore, in low-income countries with weak institutions but pressing infrastructure needs, improving the quality of monitoring and bureaucratic oversight is of paramount importance to ensure that public investment spending is not wasted.

Figure 2. Multiple Equilibria in Corruption



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