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World Development Vol. 36, No. 7, pp. 1173–1191, 2008

0305-750X/$ - see front matter

doi:10.1016/j.worlddev.2007.06.022

Threshold Effects of Corruption: Theory and Evidence

NILOY BOSE
University of Wisconsin-Milwaukee, USA

SALVATORE CAPASSO
University of Naples, Napoli, Italy

and

ANTU PANINI MURSHID *
University of Wisconsin-Milwaukee, USA
Louisiana State University, USA

Summary. — We examine the impact of corruption on the quality of public infrastructure. We propose a model in which private vendors supply governments with inputs necessary for the production of public goods. Asymmetric information between the two parties creates opportunities for vendors to earn profits. These profits can be re-distributed to government bureaucrats without impacting on the contractual form, as long as firms do not operate at a loss. Thus corruption adversely affects the provision of public goods only when it crosses a threshold. These results are examined in a sample of up to 125 countries. Consistent with our theory, we find strong evidence of a "corruption threshold."

Key words — bureaucracy, corruption, infrastructure, public investment, threshold estimation

1. INTRODUCTION

> Corruption is worse than prostitution. The latter might endanger the morals of an individual, the former invariably endangers the morals of the entire country—Karl Krauss.

Of course as economists the issue is not one of morality but simply that corruption is bad for development. Yet the rhetoric is equally charged—if not something "worse than prostitution," corruption has been likened to a "cancer" on society. [1] Such sentiments are grounded in strong theoretical foundations (Acemoglu, 1995; Blackburn, Bose, & Haque, 2004; Bardhan, 1997; Krusell & Rios-Rull, 1996) as well as in a large empirical literature which finds that corruption lowers investment and growth (Aghion, Alesina, & Trebbi, 2004; Alesina, Devleeschauwer, Easterly, Kurlat, & Wacziarg, 2003; De Soto, 1989; Mauro, 1996; Tanzi & Davoodi, 1997). Accordingly a commitment to rooting out corruption is a critical part of any developmental strategy, although its complete elimination remains an unrealistic goal. This raises the question, is there some range over which corruption, though it exists, is benign, such that the costs normally associated with it only become apparent once a certain threshold is crossed? This is the question that we explore in this paper.

There are many reasons for believing why corruption is bad for development. Existing theory, while failing to be comprehensive, casts a wide net: stressing a variety of factors, from disincentive effects on capital investment, and innovation (e.g., Krusell & Rios-Rull, 1996), to the misallocation of talent into unproductive activities (e.g., Acemoglu, 1995). Our contribution is

* A special thanks goes to four anonymous referees for insightful comments and criticisms. The authors are alone responsible for any remaining errors and omissions. Final revision accepted: June 29, 2007.

not to widen this "net" but simply recognize that the relationship between corruption and its associated costs is possibly non-monotonic. Importantly, such a hypothesis can be justified by means of a theoretical argument which is both simple and true under a reasonable set of assumptions. Supporting such a conclusion is also an empirical relationship between corruption and measures of inefficiencies which it generates that is surprisingly strong and robust.

Corruption can take many forms. The focus here is on that corruption within government bureaucracies, that is, when bureaucrats leverage their positions to further their own interests. To set the scene, consider a situation where a government procures inputs of a certain quality from firms in order to provide a public good. Public officials, or bureaucrats, are charged with acquiring these inputs in accordance with government-directives. However neither the government nor bureaucrats can distinguish good-quality inputs from bad-quality inputs. Under such circumstances, the government designs contracts so as to ensure that firms do not "cheat" by debasing the quality of inputs. In particular the government pays a premium (to firms) above the costs of production. This provides firms with an opportunity to earn positive profits, some, or all of which, can be extracted by bureaucrats (in the form of bribes) who are executors of government contracts. While these activities transfer income from firms to bureaucrats, firms, up to a point, will not renege on their contractual obligations by supplying inputs of inferior quality. The provision of the public good is therefore not adversely affected. However, when the degree of corruption (measured by the size of bribes) exceeds a certain threshold, this will no longer continue to hold true.

We provide empirical support for our model by testing for threshold effects in the relationship between corruption and measures of the quality of public infrastructure investments, using a procedure suggested in Hansen (2000). Our results, which are based on a large cross-section of countries, suggest two distinct regimes. One in which the incidence of corruption is high, and its effect on the quality of public infrastructure is strongly negative, and one for relatively low levels of corruption where its effect is neutral or perhaps even slightly positive. It is important to recognize that these threshold effects are not simply capturing the relationship between the quality of public infrastructure and the level of economic development. Threshold effects are apparent even when we control for measures of development.

The remainder of this paper is organized as follows: In Section 2, we present in detail our theoretical framework and its implications for the relationship between corruption and the quality of public investment. Section 3 describes the data and discusses our empirical methodology. In Section 4, we present our results. In Section 5, we offer some comments with regard to our analysis. Finally Section 6 concludes.

2. THEORETICAL FRAMEWORK

(a) *The Environment*

Below we present a simple partial equilibrium setup in which a government, or planner, provides a public good by procuring inputs necessary for its production. To contextualize our model, consider for instance a public project, such as the construction of a dam, a road, or a bridge, which utilizes large quantities of concrete. We assume that there are differences in the quality of inputs. Specifically there are two types of inputs—a low-quality input and a high-quality input. Consider for instance the difference between ordinary concrete and reinforced concrete. Ordinary concrete is a mixture of cement and stone aggregate that is well suited for structures subject to high compressive forces, however any appreciable tension can lead to cracking or separation. Reinforcing this concrete using steel bars (rebars) yields a composite that is highly resistant to tensile forces. The addition of rebars prior to a concrete pour therefore yields a significant and *discrete* improvement in quality. [2] We capture these differences by assuming some variation in the marginal productivity of each input. In particular, suppose that one unit of the high-quality input, input-H, generates s_H units of the public good, while one unit of the low-quality input, input-L, yields $s_L < s_H$ units of the good. [3]

We assume that low-quality inputs, such as ordinary concrete, are generic. They have alternative uses and as such they are readily available in the market at a competitive price. However, it is always preferable to use at least some quantity of reinforced concrete making it necessary for the government to obtain high-quality inputs, H. By their very nature, high-quality inputs must be made to order and are not readily available from input markets. Again this is not unrealistic. Unlike ordinary concrete, reinforced concrete is usually built to specifications due to the presence of rebars. Accordingly it is not unreasonable to expect ordinary concrete to be relatively inexpensive to produce in contrast to reinforced concrete. Thus we assume that the marginal cost of producing L, c_L, is lower than the marginal cost of producing H, $c_H > c_L$.

(b) *The government and government officials*

We assume that the government's objective is to maximize the provision of a public good. The amount of resources allocated for the construction of public infrastructure projects, R, is *fixed*. This lack of flexibility in the available resources reflects both the realities of government budgetary constraints (especially in developing countries) and the common practice of earmarking a *fixed* amount of resources toward particular ventures. We assume that when a government undertakes public infrastructure investments, these projects are completed. Thus for instance a project to construct a road connecting two towns yields a final product that is one entire road, *not* half a road. Consequently, for any given project, the variability in the provision of the public good should be assessed on the basis of *quality* rather than quantity. We assume therefore that the government's goal is to maximize the quality of the public good subject to its budget constraint. In order to achieve this goal, it designs a set of procurement rules (contracts) before handing over responsibility to a group of public officials or bureaucrats. Bureaucrats are charged with the task of procuring inputs subject to the rules set by the government.

(c) *Information*

To the government and to bureaucrats a block of ordinary concrete is indistinguishable from a block of reinforced concrete. Thus *ex ante* the quality of inputs is the private information of firms. Thus unlike some earlier literature where informational asymmetries appear in the cost structure of firms (Laffont & Tirole, 1993), in the current setup the uncertainty is in project characteristics, which are *not* observable and therefore *not* contractable. This focus draws support from a more recent literature (e.g., Bajari & Tadelis, 2001) that points to an array of public goods the quality of which is not readily verifiable and/or is only observable under special conditions over which the principal has no direct control. For example, the structural quality of a dam or a bridge is truly tested only in extreme conditions, during an earthquake or a flood.

Since ordinary concrete is cheaper to produce than reinforced concrete, suppliers have incentives to cheat by "passing-off" ordinary concrete for reinforced concrete. However, in the event that firms supply low-quality inputs, with some probability, $(1-\phi) < 0.5$, these actions are detected. This happens, for instance, if structural deficiencies and imperfections in the final good are revealed *ex post*. If this is the case, suppliers can avoid prosecution by supplying the government high-quality inputs as promised. [4] The presence of moral hazard plays an important role in determining the procurement rules set by the government, which we discuss below.

(d) *Terms of procurement under asymmetric information*

Unlike generic inputs such as concrete, which are traded in input markets, high-quality inputs, such as reinforced concrete, are produced on a made-to-order basis. Consequently government contracts set both a price, p_H, and a quantity Q_H. In the presence of informational asymmetry, the government designs the optimal contract by solving the following problem:

$$\max_{(p_H, Q_H)} q = s_H Q_H, \tag{1}$$

subject to

$$p_H Q_H \leqslant R, \tag{2a}$$
$$(p_H - c_H)Q_H \geqslant 0, \tag{2b}$$
$$(p_H - c_L)\phi - (1-\phi)c_H \leqslant (p_H - c_H), \tag{2c}$$
$$c_H > c_L, \quad Q_H > 0. \tag{2d}$$

As we noted above q should be interpreted as a measure of quality, for example, the average thickness of paved surfaces on a road or the structural quality of a bridge or a dam.

Eqn. (2a) is simply the government's resource constraint. The individual rationality constraint given by Eqn. (2b) states that firms must be making non-negative profits, while the incentive compatibility constraint given in Eqn. (2c) ensures that it is not in a firm's best interest to supply low-quality inputs. The following proposition describes the optimal contract:

Proposition 1. If c_L is small such that $\frac{\phi}{1-\phi} \geqslant \frac{c_H}{c_H - c_L}$, the optimal price-quantity vector, (p_H^*, Q_H^*), is given by

$$p_H^* = \frac{\phi(c_H - c_L)}{1 - \phi}, \tag{3a}$$

$$Q_H^* = \frac{R}{p_H^*}. \tag{3b}$$

Proof. See Appendix A. □

The intuition behind this result is straightforward. A low value of c_L means that there are incentives for firms to cheat for positive values of p_H. Now, in designing the optimal contract, the government must ensure that such cheating does not take place. At the same time, the government has no incentive to offer firms a price higher than what is required to deter cheating. This means that the incentive compatibility constraint (Eqn. (2c)) must bind at the optimum, yielding the price, p_H^*. At the same time, the government must ensure that no resources are wasted. Accordingly, the resource constraint of the government, given in Eqn. (2a), must also bind, which together with the value of p_H^* pins down the optimal procurement quantity Q_H^*.

Before we proceed further, it is important to highlight the role of informational asymmetry for our story. Consider a situation where the government has full information and is able to distinguish *ex ante* the quality of inputs while also controlling the actions of suppliers. Under such circumstances, the government can ensure that it receives type-H inputs, while also pulling down its offer price to the marginal cost of production, c_H. Consequently under full information the opportunity for firms to earn positive profits disappears. By contrast, under asymmetric information, the government must pay a premium above c_H to ensure that the incentive compatibility constraint of firms is not violated. Consequently firms earn positive profits. This feature plays an important role in the derivation of subsequent results. [5]

Finally, note that the value of government's objective function evaluated at Q_H^* is $\frac{(1-\phi)s_H R}{(c_H - c_L)\phi}$. In contrast the government receives $\frac{s_L R}{c_L}$ if only the low-quality input is procured. Thus, the relation $\frac{s_H}{s_L} > \frac{\phi(c_H - c_L)}{(1-\phi)c_L}$ must hold for the government to be at all interested in the high-quality input. Throughout we assume that s_L is low enough that the above condition holds.

(e) *Threshold effects in corruption and government bureaucracy*

In practice, procuring inputs is a complicated process involving several administrative procedures designed and vetted by bureaucrats. It is often the case that bureaucrats misuse this power to their own advantage. For example, a corrupt bureaucrat can delay the registration of firms as recognized government vendors. Alternately, bureaucrats may delay releasing payments to firms for its services and/or goods provided. [6] Since these actions are costly for firms, bureaucrats can demand bribes, b, in exchange for eliminating these costs. The innovation of our analysis is to point out that negative effects of such illegal activities emerge only when the size of bribes exceeds a particular threshold. Proposition 2 states this result precisely.

Proposition 2.

(i) There exists a threshold τ, where

$$\tau = \frac{\phi(c_H - c_L) - c_H(1-\phi)}{\phi(c_H - c_L)} R > 0, \tag{4}$$

such that for all $b \leqslant \tau, (p_H^*, Q_H^*)$ is unaffected.

(ii) For all $b > \tau, \widetilde{Q}_H < Q_H^*$ and $\tilde{p}_H > p_H^*$, where $\tilde{p}_H \propto b$ and $\widetilde{Q}_H \propto \frac{1}{b}$.

Proof See Appendix A. □

Again the intuition behind this result is simple. Note that the bribe extracted by bureaucrats acts like a lump-sum tax on firms; it raises the costs of production *irrespective* of whether firms produce low-quality or high-quality inputs. Bribes therefore have implications for firms' individual rationality (participation) constraints, but not for their incentive compatibility constraints. This matters because for the original contract (p_H^*, Q_H^*), the binding constraint is not the individual rationality constraint but rather the incentive compatibility constraint. Thus, as long as the participation constraint is satisfied, bureaucrats can extract bribes without affecting firms' supply decisions. This establishes the existence of a threshold level of bribes, τ, for which the participation constraint holds with equality for the pair (p_H^*, Q_H^*).

Suppose however that bribes paid to bureaucrats exceed the threshold, τ. Also, suppose the government recognizes this corruption and takes this into account when designing contracts. Clearly, since firms will no longer break even at a price p_H^*, the government is forced to offer a higher price $\tilde{p}_H$. Given the limited size of government budgets, this translates into a lower quantity, $\widetilde{Q}_H$, which the government can now afford to purchase from firms. These observations corroborate well with reality. As a result of excessive corruption, inflated cost of public expenditure co-exists with the low quality of existing public infrastructures in many countries (Gupta, Davoodi, & Tiongson, 2000; Tanzi & Davoodi, 1997).

One may, however, argue that the government need not take as given, corruption within its bureaucracy. Instead it may wish to deter corrupt practices by implementing a monitoring technology. Such technologies however are likely to be costly, reducing resources available for providing public goods. Thus excessive corruption would, in any event, adversely affect the provision of public goods.

3. DATA AND METHODOLOGY

(a) *Methodology*

Our theory has straightforward and testable implications. Corruption within government bureaucracies can lower the quality of public investments. At the same time the possibility exists for these failures to have no ill-effects. Which of these outcomes correctly describes the relationship between government failures and public investment will depend on the extent of corruption. We can describe these relationships more formally as follows:

$$q_i = \theta_1' x_i + \varepsilon_i, \quad b_i \leqslant \tau, \tag{5a}$$

$$q_i = \theta_2' x_i + \varepsilon_i, \quad b_i > \tau, \tag{5b}$$

where q_i measures the quality of public investments, in country i, b_i is a threshold variable, corresponding to the amount of bribes paid to bureaucrats, and x_i is a set of controls.

This specification is quite general in that it imposes no cross-regime restrictions on our parameters. However since our focus is on how the effect of corruption changes, it will be useful to restrict some, or all, other model parameters. While a continuous spline specification may be too restrictive, ideally we would want to allow the coefficient on our corruption index as well as the constant term to change. [7] Formally, we would want to estimate the following specification:

$$q_i = \alpha_1 + \beta' x_i + \theta_1 b_i + \varepsilon_i, \quad b_i \leqslant \tau, \tag{6a}$$

$$q_i = \alpha_2 + \beta' x_i + \theta_2 b_i + \varepsilon_i, \quad b_i > \tau, \tag{6b}$$

q_i and b_i are as above, x_i is re-defined as the set of control variables excluding b_i.

Eqns. (6a) and (6b) reduce to a single equation:

$$q_i = \alpha_2 + \beta' x_i + \theta_2 b_i + \delta' b_i(\tau) + \varepsilon_i, \tag{7}$$

where $\delta' \equiv (\alpha_2 - \alpha_1\theta_2 - \theta_1)$, $b_i(\tau) \equiv (1 b_i) I(\tau)$, and $I(\tau) \equiv \{b_i \leqslant \tau\}$ is an indicator variable. Note that for any given τ, (7) is linear in its parameters, thus the simplest way to estimate τ is through conditional least squares (Hansen, 2000). This involves choosing $\hat{\tau}$ so as to minimize $S(\tau)$, where $S(\tau)$ is the sum of squared residuals for any given value of τ.

In order to test the statistical significance of a threshold effect typically we would want to test the null hypothesis of "no threshold," that is, $H_0 : \theta_1^* = \theta_2^*$, where $\theta_j^{*\prime} = (\alpha_j \theta_j)$ for $j = 1, 2$. However, since τ is only identified under the alternative, distributions of classical test statistics, such as the Wald and likelihood ratio tests, are not asymptotically chi-squared. In essence this is because the likelihood surface is flat with respect to τ, consequently the information matrix becomes singular and standard asymptotic arguments no longer apply. There are methods for handling hypothesis testing within these contexts. In some instances, we can bound the asymptotic distribution of likelihood ratio statistics (Davies, 1987), alternatively their asymptotic distribution can be derived by bootstrap methods. Hansen (2000) proposes the latter. The appropriate test statistic is

$$LR_0 = \frac{S_0 - S_1}{\hat{\sigma}^2},$$

where S_0 and S_1 are, respectively, the residual sum of squares under the null $H_0 : \theta_1^* = \theta_2^*$ and the alternative $H_1 : \theta_1^* \neq \theta_2^*$, and $\hat{\sigma}^2$ is the residual variance under the alternative H_1.

In the presence of heteroscedasticity a "wild bootstrap" is preferable to standard residual bootstrapping (Davidson & Flachaire, 2001; Wu, 1986). This is done in a number of stages. First, by transforming the residuals, $\hat{\varepsilon}$, from our regression analysis using the following transformation: $f(\hat{\varepsilon}_i) = \frac{\hat{\varepsilon}_i}{(1-h_i)^{1/2}}$, where h_i is the ith diagonal of the projection matrix $X(X'X)^{-1}X$ and X

is simply our matrix of regressors in (7), that is, $X_i' = [1 x_i b_i b_i(\tau)]$. Next, we generate 999 replications of the random error, u_i, where

$$u_i = \begin{cases} 1 & \text{with probability } 1/2, \\ 0 & \text{with probability } 0. \end{cases}$$

Finally we can use the transformed residuals, $f(\hat{\varepsilon}_i)$, and the bootstrap errors, u_i, to create a bootstrap sample under the null as follows:

$$q_i^* = \hat{\alpha}_2 + \hat{\beta}' x_i + \hat{\theta}_2 b_i + \hat{\delta}' b_i(\hat{\tau}) + f(\hat{\varepsilon}_i) u_i.$$[8]

When threshold effects are present, $\hat{\tau}$ is consistent (Hansen, 2000). However in discontinuous threshold regression models, the asymptotic distribution of $\hat{\tau}$ is non-standard. Hansen (2000) proposes calculating confidence intervals by forming a "no-rejection region" based on likelihood ratio tests on τ. Specifically we would want to test the null: $H_0{:}\tau = \tau_0$, rejecting for large values of $LR_1(\tau_0)$, where

$$LR_1(\tau) = \frac{S_1(\tau) - S_1(\hat{\tau})}{\hat{\sigma}^2}.$$

Hansen (2000) has derived the asymptotic distribution of $LR_1(\tau_0)$ which while non-standard requires little additional computation.

Below we apply these methods to estimate the effect of corruption on measures of the quality of public infrastructure in a cross-section of countries.

(b) *Data*

Since our theory is formed on the basis of "flows" of contracts, empirical testing should be based on measures of the quality, q, of new public capital *investments*. While sectoral breakdowns on capital outlays are available in *Government Financial Statistics*, these can only serve as a basis for a series on new infrastructure *expenditures* (which is more closely related to R), *not* infrastructure quality. The only measures of quality that exist are those of the quality of the *stock* of public infrastructure. However, these are likely to be highly correlated with the quality of new capital investments. Thus as our dependent variables, we use measures of the quality of the stock of public infrastructure.

Data on our quality measures are available over a 10-years period from 1990 to 2000. Accordingly our analysis is based on decadal averages, however generally much of the variation within the sample is across countries. Country-coverage is varied however in some simple specifications, and our sample covers up to 125 countries. Below we discuss our measures of quality, as well as the variable we use to measure corruption. Our measures of the quality of public infrastructure are drawn from a database compiled by Estache and Goicoechea (2005). These data are drawn from a variety of publicly available sources including the *International Energy Agency*, *World Health Organization*, and *World Development Indicators*. In this paper, we consider three measures of quality. These include a measure of the quality of electricity distribution, the quality of roads, and the quality of water supply.

The quality of electricity is measured as the percent of electricity generated that is successfully distributed. This variable is calculated using data on electric power transmission and distribution losses as a percent of total power generated, averaged during 1990–2000. Power losses include electricity lost in its generation and delivery, as well as those caused by unmetered supply.

We use a measure of the length of paved road surfaces (normalized by country size) as a measure of the quality of the road network. We take the 10-years average of these data from 1990 to 2000. An alternative measure of road quality is the percent of road surfaces that are paved. However this measure is often problematic. In particular in larger countries, often substantial parts of the road network are not paved. As a result, according to this measure, roads in Bhutan (along with 67 other countries in our sample) are superior to that in the United States.

Finally, as our measure of water quality, we use data on the percent of the population with access to improved water sources. Again we take a 10-years average of these data during 1990–2000.

We recognize that each of these measures is imperfect. This is particularly true of our measures of road and water quality. Both are more closely related to the "size" or quantity of public infrastructure rather than its quality. Unfortunately accurate data on the average quality of road surfaces, as also on the average quality of water supplied to households, are unavailable for a large enough sample in order for cross-country analysis to be viable. Moreover, our measure of the "quality" of roads, that is, the length of paved road surfaces, is problematic since it does not take into account the width of roads (see below), as such it is an imperfect measure of both the "size" and the quality of the road network.

At the same time, it is inaccurate to believe that these measures are uninformative altogether as to the quality of public infrastructure. Even while some of these measures are more accurately described as measures of size or quantity, it is often the case that the quantity of infrastructure is positively associated with its quality. Moreover, the use of these variables, as measures of infrastructure quality, is now standard in the literature. Thus while we accept that we can only measure the quality of infrastructure imprecisely, as a first step, our results from our cross-country analysis are easily interpretable against standard benchmarks in the literature which rely on these very same measures.

Our measure of corruption is based on Transparency International's corruption perception index. The index is appropriately re-defined so that it varies between 0 and 10, where higher values are associated with higher levels of corruption. [9] Unfortunately the earliest date for which these data are available is 1995. We therefore measure corruption as the average value of this index during 1995–2000. If data within this period are not available, we take the earliest year for which data are available.

Our other explanatory variables include controls for development—initial *per capita* GDP and secondary school enrollment ratios. We also control for population density, since lower population densities often necessitate larger *per capita* investments in order to maintain a certain quality of service from public infrastructure. Thus for instance we often find that quality of roads connecting rural areas is inferior relative to roads in urban areas. Finally we introduce controls for government deficits and country openness. These variables aim to capture the effect of government budgetary issues on public infrastructure quality. The effect of deficits on public infrastructure spending is obvious; however, country openness may also matter since a large tradable goods sector can imply a steady and larger tax base for governments.

4. RESULTS

We begin our analysis by estimating a simple benchmark specification where we regress decadal averages of the quality of public infrastructure, against logs of initial real *per capita* income and our corruption measure. [10] At this stage we do not attempt to introduce additional controls; moreover, we impose the assumption of linearity on our model-specification (Table 1). Not unexpectedly, *per capita* income in 1990 is found to be strongly correlated with the quality of public infrastructure. However corruption only has a negative effect on the quality of electricity and roads, and even then the result is only statistically significant in one case. As our analysis below suggests, this could be due in part to the presence of strong threshold effects.

In Table 2, we consider the possibility of threshold effects. The table is divided into two panels. Panel A allows all model parameters to change when corruption crosses a particular threshold. This specification therefore corresponds to Eqns. (5a) and (5b). The model in Panel B restricts the coefficient on *per capita* income to be constant across both regimes. This is effectively the specification described in Eqns. (6a) and (6b) (alternatively Eqn. (7)). Our analysis points to the presence of strong threshold effects. In most cases the null hypothesis can be rejected at least at the five percent level. Some of the variation within the data is captured by parameter instability in the coefficient on

Table 1. *Impact of corruption on the quality of public infrastructure: simple OLS*

Independent variable	Quality of electricity (1)	Quality of water (2)	Quality of roads (3)
Constant	0.7151	0.0249	−1.2623
	(0.0624)	(0.1339)	(0.6985)
Income	0.0233	0.0979	0.2557
	(0.0060)	(0.0137)	(0.0584)
Corruption	−0.0260	0.0261	−0.1411
	(0.0099)	(0.0204)	(0.2057)
Observations	105	105	125
R^2	0.35	0.46	0.25

Notes: Both initial GDP and the corruption index are measured in logs. Standard errors are reported in parentheses. A full description of all variables is offered in Appendix B.

Table 2. *Threshold effects in corruption*

	Quality of electricity		Quality of water		Quality of roads	
	Regime 1 Corruption <= 1.7538 (1a)	Regime 2 Corruption > 1.7538 (1b)	Regime 1 Corruption <= 1.9320 (2a)	Regime 2 Corruption > 1.9320 (2b)	Regime 1 Corruption <= 1.3987 (3a)	Regime 2 Corruption > 1.3987 (3b)
Panel A						
Constant	0.7068	1.9601	0.0690	3.2949	0.6455	0.0361
	(0.0455)	(0.2520)	(0.1750)	(0.7702)	(5.9433)	(0.3962)
Income	0.0227	−0.0097	0.0926	0.1013	0.0569	0.1034
	(0.0045)	(0.0075)	(0.0178)	(0.0213)	(0.5888)	(0.0226)
Corruption	0.0020	−0.5495	0.0251	−1.5964	0.6434	−0.3048
	(0.0046)	(0.1175)	(0.0226)	(0.3700)	(0.3419)	(0.1545)
Threshold	1.75		1.93		1.40	
95% CI	(1.71, 1.83)		(1.87, 2.05)		(1.16, 1.46)	
Bootstrap *p*-value	(0.00)		(0.03)		(0.28)	
Observations	105		105		125	
Joint R^2	0.55		0.55		0.41	
Panel B						
Constant	0.9340	1.8286	0.0356	3.3525	0.2191	0.0885
	(0.0570)	(0.2264)	(0.0135)	(0.7493)	(0.6544)	(0.7583)
Income	0.0000	0.0000	0.0960	0.0960	0.0998	0.0998
	(0.0057)	(0.0057)	(0.1330)	(0.0135)	(0.0499)	(0.0499)
Corruption	−0.0171	−0.5165	0.0297	−1.6080	0.6595	−0.3190
	(0.0069)	(0.1070)	(0.0183)	(0.3688)	(0.3777)	(0.2330)
Threshold	1.75		1.93		1.40	
95 % CI	(1.67, 1.86)		(1.88, 2.05)		(1.40, 1.46)	
Bootstrap *p*-value	(0.00)		(0.02)		(0.05)	
Observations	105		105		125	
Joint R^2	0.53		0.55		0.41	

Notes: Both initial GDP and the corruption index are measured in logs. A full description of all variables is offered in Appendix B. Standard errors are in parentheses, except bootstrap *p*-values and confidence intervals around estimated thresholds, which are also reported in parentheses. Bootstrap *p*-values were generated on the basis of 999 iterations (see text for details). Estimation was performed using a code written by the authors for Gauss. The code is available on request.

income (Table 2, Panel A). However, in most instances, the association between *per capita* incomes and infrastructure quality remains positive and statistically significant across regimes. This is not the case for corruption. The coefficient on corruption changes abruptly across the two regimes. While corruption shows no association, or even a positive association, with infrastructure quality in low-corruption regimes, this relationship turns sharply negative once the value of corruption crosses a particular threshold. Moreover, in each instance this negative effect of corruption is highly statistically significant.

It is important to recognize that even when we restrict the coefficient on income to be constant across regimes these conclusions are largely unaffected. Evidently much of the cross-regime variation in our data can be explained by the instability in the corruption index. This is clearly evident in plots of the partial correlations between our three quality measures and the corruption index (Figure 1). The sharpest threshold effects are evident in the relationship between corruption and the quality of electricity and water supply. Evidence of threshold effects is weakest when we focus on measures of road quality (reasons for this are discussed below).

In Table 3, we extend our analysis by introducing a number of other controls. Secondary school enrollment ratios are introduced as an additional control for the level of development. A control for population densities is also included to examine whether increases in population densities raise infrastructure quality (by lowering *per capita* average costs associated with infrastructure provision). In addition we control for the size of government balances and a measure of trade openness.

The inclusion of these additional controls provides some insights into other determinants of the quality of infrastructure. For instance, we find that the quality of water and roads improves with *per capita* income and school enrollment ratios, while higher population densities are associated with improvements in all three areas. By contrast, government budgetary issues (as measured by the size of government budget deficits and openness) are not important determinants of the cross-sectional variation in infrastructure quality.

Within the current context the important result is that the inclusion of additional controls does not appreciably affect the underlying conclusion that threshold effects are present. This conclusion is strongest when quality is assessed in terms of the production and distribution of electricity and water. In general the null hypothesis that no threshold is present can be rejected (at least) at the five percent level. Evidence against threshold effects is weakest when quality is measured as the length of paved road surfaces: *LR*-tests of the null yield results varying between borderline statistical significance and insignificance (*p*-values between 0.07 and 0.17). Moreover, the coefficient on corruption in the high-corruption regime, though negative, was never statistically significant. This weaker result using road-quality measures should not be surprising, since our data on the quality of roads are particularly noisy. This reflects a number of difficulties with our measure. First, data on the *length* of paved road surfaces are not necessarily a good proxy for the surface *area* of roads, since there is considerable variation in the width of roads. Second, there is considerable variation in the quality of paved road surfaces. Third, the definition of what constitutes roads varies. Thus in some countries only roads under central government control are included in the measure of paved surfaces, and in other countries a more complete measure of the length of the road network is provided (Canning, 1998).

The resulting variability in our measure, particularly in the low-corruption regime, is evident in Figure 1. Consequently it is difficult to isolate a threshold, if in fact a threshold is present. Even so a conclusion that threshold effects are present (in the quality of roads) is not without merit—the results are certainly suggestive, if not always statistically significant.

It is worth noting that for each of our quality measures, thresholds occur at different levels. In Table 4, we group countries into different categories according to these thresholds (countries are also grouped by income and geographical location). Countries are grouped into five categories corresponding to four separate thresholds 1.4, 1.6, 1.75 and 1.92. The threshold at which corruption adversely affects road construction is 1.4 (and also 1.6, see discussion below). It is higher for electricity production (1.75) and higher still for water supply (1.92). Thus the thresholds at which ill-effects of corruption operate can be high: roughly 60% of countries belong to the low corruption regime when its adverse effects are measured *vis-à-vis* the quality of water. By contrast, the threshold is much lower when our quality is assessed on the basis of paved roads: roughly 20% of countries lie in the low-corruption regime.

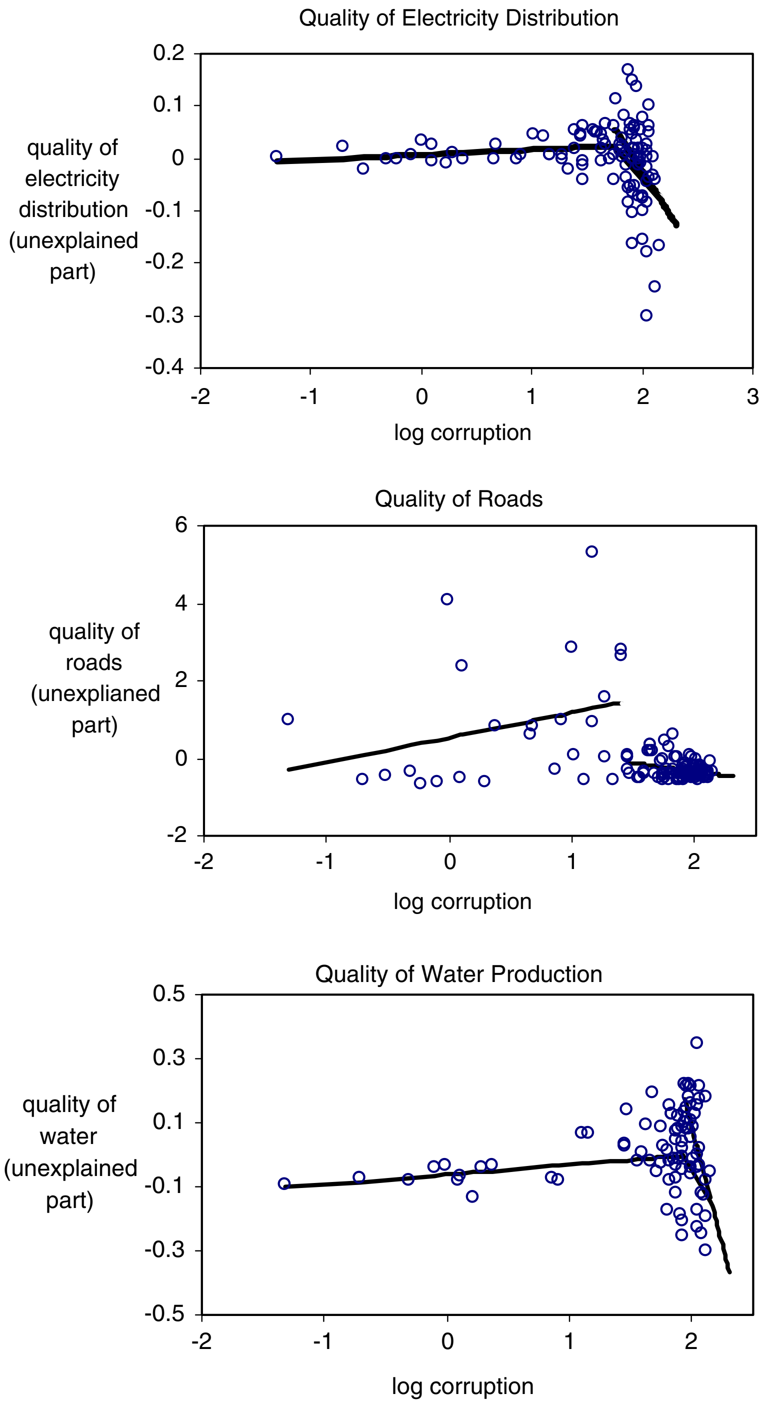

Figure 1. *Partial correlations between quality of public infrastructure projects and corruption index. Notes: Partial correlations are based on residuals from a regression of quality variables against log initial GDP estimated without assuming the existence of a threshold.*

Table 3. *Threshold effects in corruption: general specification*

	Quality of electricity		Quality of water		Quality of roads	
	(1)	(2)	(3)	(4)	(5)	(6)
Constant regime 1[a]	0.7113	0.9066	−0.0530	−0.0301	0.1349	0.2122
	(0.0437)	(0.0577)	(0.1335)	(0.2004)	(0.5286)	(0.6679)
Constant regime 2[b]	2.0804	1.8363	2.5662	2.8075	−0.1319	−0.0653
	(0.2751)	(0.3110)	(0.6284)	(0.7822)	(0.6450)	(0.8193)
Income	0.0209	0.0082	0.0817	0.0782	0.0592	0.0387
	(0.0062)	(0.0069)	(0.0170)	(0.0220)	(0.0479)	(0.0734)
Schooling	−0.0149	0.0005	0.1241	0.1901	0.3761	0.4146
	(0.0326)	(0.0004)	(0.0659)	(0.0542)	(0.1421)	(0.2260)
Population	0.0071	0.0011	0.0265	0.0173	−0.4510	−0.5347
	(0.0023)	(0.0047)	(0.0086)	(0.0075)	(0.1527)	(0.1480)
Population^2					0.0961	0.1116
					(0.0215)	(0.0205)
Trade		0.0056		0.0037		0.0231
		(0.0082)		(0.0166)		(0.0795)
Government balance		−0.1452		0.1833		−1.3305
		(0.2012)		(0.3938)		(1.2806)
Corruption regime 1[a]	−0.0041	−0.0197	0.0373	0.0477	0.4224	0.4496
	(0.0049)	(0.0072)	(0.0191)	(0.0193)	(0.2302)	(0.2605)
Corruption regime 2[b]	−0.5687	−0.5417	−1.2535	−1.3450	−0.0884	−0.0549
	(0.1140)	(0.1527)	(0.3058)	(0.3687)	(0.1776)	(0.2267)
	1.74	1.74	1.92	1.92	1.40	1.40
95% CI	(1.66, 1.88)	(1.27, 1.92)	(1.93, 1.97)	(1.92, 1.95)	(1.40, 1.45)	(1.40, 1.46)
Bootstrap *p*-value	0.00	0.04	0.03	0.01	0.07	0.17
Observations	104	73	103	69	125	88
Joint R^2	0.54	0.58	0.61	0.75	0.74	0.78

Notes: The variables initial GDP, corruption, population, and population^2 are measured in logs. The variable population^2 is the square of log of population density. A full description of all variables is offered in Appendix B. Standard errors are in parentheses, except bootstrap *p*-values and confidence intervals around estimated thresholds, which are also reported in parentheses. Bootstrap *p*-values were generated on the basis of 999 iterations (see text for details). Estimation was performed using a code written by the authors for Gauss. The code is available on request.
[a] Regime 1 is the low-corruption regime, that is, when corruption $\leqslant \tau$.
[b] Regime 2 is the high-corruption regime, that is, when corruption $> \tau$.

The variation in cut-off points at which corruption has harmful effects is not surprising. After all, our measure of corruption is aggregated. The extent of corruption in road construction need not be the same as that in the power-generation industry. Since data on corruption are not available at the industry level, we cannot test whether corruption thresholds are similar across industries. However, even if disaggregated data were available, there is no reason why we would expect thresholds to be the same across different industries. Differences in industry profitability for instance are potentially important determinants of the extent to which corruption matters.

Since the (low) threshold at which corruption affects road quality neatly divides countries into industrialized and non-industrialized, it is worth considering whether our results are driven by unobserved differences between developed and developing countries, or whether they are actually due to threshold effects in corruption. We test this in Table 5 by omitting high-income OECD countries from our sample. Restricting the sample in this way has no appreciable effect on our results pertaining to the quality of electricity and water. The threshold at which corruption has negative effects is unaffected in both these cases. However, not surprisingly, our results for the quality of roads do change. In the specification estimated in column 3, which restricts cross-regime coefficients on all variables except corruption (and the intercept), there is no evidence of a threshold. Interestingly in this case, the coefficient on corruption in the low regime is negative, and it is essentially zero in the high regime. However, this result is not particularly useful, both

Table 4. *Countries grouped by corruption regime, income level and region*

Value of corruption index	Region	High income	Middle income	Low income
Corruption index ⩽ 1.40. Low-corruption regime: electricity, roads and water	East Asia and the Pacific	New Zealand, Singapore, Australia, Hong Kong, Japan		
	Latin America and the Caribbean		Barbados, Chile	
	Middle East and North Africa	Israel, Malta, Portugal	Oman, Bahrain	
	North America	Canada, United States		
	Sub-Saharan Africa		Botswana	
	Western Europe	Denmark, Finland, Sweden, Iceland, Norway, Netherlands, Switzerland, Luxembourg, United Kingdom, Ireland, Germany, Austria, France, Belgium		
Corruption index ⩽ 1.60. Low-corruption regime: electricity, roads and water	East Asia and the Pacific		Malaysia	
	Eastern and Central Europe	Slovenia	Estonia	
	Latin America and the Caribbean		Costa Rica	
	Middle East and North Africa		United Arab Emirates, Qatar, Tunisia	
	Sub-Saharan Africa		Namibia, South Africa	
	Western Europe	Cyprus, Spain		
Corruption index between 1.60 and 1.75. Low-corruption regime: electricity and water	East Asia and the Pacific			Mongolia
	Eastern and Central Europe		Hungary, Czech Republic, Poland	
	Latin America and the Caribbean		Trinidad and Tobago, Suriname, Uruguay	
	Middle East and North Africa	Kuwait	Jordan	
	Sub-Saharan Africa		Mauritius, Seychelles	
	Western Europe	Greece		

Value of corruption index Region High income Middle income Low income

Corruption index between 1.75 and 1.92. Low-corruption regime: water	East Asia and the Pacific		Korea	
	Eastern and Central Europe		Lithuania, Belarus, Slovak Republic, Turkey, Macedonia, FYR, Bulgaria, Bosnia and Herzegovina, Croatia	
	Latin America and the Caribbean		Belize, Cuba, El Salvador, Jamaica, Brazil, Argentina, Panama, Dominican Republic, Mexico	
	Middle East and North Africa		Morocco, Saudi Arabia, Syrian Arab Republic	
	South Asia		Sri Lanka	
	Sub-Saharan Africa			Malawi, Zimbabwe, Zambia, Senegal, Ghana, Benin, Ethiopia
	Western Europe	Italy		
Corruption index > 1.92. Low-corruption regime: none.	East Asia and the Pacific		Thailand, Philippines, Papua New Guinea	China, Vietnam, Indonesia, Myanmar
	Eastern and Central Europe		Latvia, Romania, Kazakhstan, Russian Federation, Albania, Georgia, Ukraine, Uzbekistan, Yugoslavia (Serbia/Montenegro)	Moldova, Armenia, Kyrgyz Republic, Turkmenistan, Tajikistan, Azerbaijan
	Latin America and the Caribbean		Guatemala, Colombia, Bolivia, Ecuador, Venezuela, RB, Paraguay	Nicaragua, Honduras, Haiti
	Middle East and North Africa		Egypt, Iran, Lebanon, West Bank and Gaza, Algeria, Libya, Iraq	Yemen
	South Asia			Nepal, India, Bangladesh, Pakistan
	Sub-Saharan Africa			Mali, Burkina Faso, Mozambique, Cote d'Ivoire, Gambia, The, Eritrea, Madagascar, Uganda, Congo, Rep., Sudan, Sierra Leone, Kenya, Niger, Tanzania, Congo, Dem. Rep., Cameroon, Angola, Chad, Nigeria

Notes: Countries listed are those for which corruption, regional, and income data are available data, and not all countries listed appear in regressions since data on infrastructural quality were unavailable for all countries listed here.

Table 5. *Threshold effects in corruption in a sample excluding high-income-OECD countries*

	Electricity	Water	Quality of Roads		
	(1)	(2)	(3)	(4a)	(4b)
Constant regime 1[a]	1.0699	−0.2274	1.6984	0.9008	
	(0.1127)	(0.1886)	(0.9325)	(2.7010)	
Constant regime 2[b]	1.9371	2.3627	−0.0120		0.6248
	(0.2590)	(0.6373)	(0.7395)		(0.3607)
Income	−0.0075	0.0889	0.0649	−0.3571	0.0249
	(0.0094)	(0.0172)	(0.0396)	(0.3645)	(0.0171)
Schooling	0.0031	0.1244	0.3699	1.7294	0.2986
	(0.0426)	(0.0653)	(0.1340)	(0.8777)	(0.0637)
Population	−0.0038	0.0365	−0.5264	−0.9448	−0.0062
	(0.0064)	(0.0120)	(0.2713)	(0.3176)	(0.0737)
Population^2			0.0962	0.1977	0.0133
			(0.0401)	(0.0486)	(0.0102)
Corruption regime 1[a]	0.0611	0.0852	−0.9294	1.2727	
	(0.0256)	(0.0569)	(0.7263)	(0.9602)	
Corruption regime 2[b]	−0.5383	−1.1950	−0.0160		−0.5109
	(0.1143)	(0.3057)	(0.3192)		(0.1740)
	1.74	1.92	1.62	1.60	
95% CI	(1.56, 2.00)	(1.92, 2.02)	(1.62, 1.62)	(1.6 0, 1.62)	
Bootstrap *p*-value	0.02	0.03	0.64	0.04	
Observations	81	91	103	103	
Joint R^2	0.43	0.57	0.71	0.87	

Notes: The variables initial GDP, corruption, population and population^2 are measured in logs. The variable population^2 is the square of log of population density. A full description of all variables is offered in Appendix B. Standard errors are in parentheses, except bootstrap *p*-values and confidence intervals around estimated thresholds, which are also reported in parentheses. Bootstrap *p*-values were generated on the basis of 999 iterations (see text for details). Estimation was performed using a code written by the authors for Gauss. The code is available on request.
[a] Regime 1 is the low-corruption regime, that is, when corruption $\leqslant \tau$.
[b] Regime 2 is the high-corruption regime, that is, when corruption $> \tau$.

because the coefficients are not statistically significant, and because the null of a linear relationship between corruption and road quality cannot be rejected (p-value = 0.64).

The absence of a threshold in this instance however can be attributed to two factors. First, the variability in our road-quality data continues to be a concern. Second, there is now considerable evidence of cross-regime parameter heterogeneity in our other controls (Table 5, columns 4a and 4b). Population densities for instance have strong quadratic effects in the low-corruption regime, while in countries with high corruption the relationship is linear. In general larger coefficients on our controls in the low regime are consistent with greater variability in our quality measure within these countries. The pattern is far more concentrated within high-corruption countries (where generally roads are of inferior quality). Once we allow for cross-regime parameter heterogeneity, evidence of a threshold is strong (p-value of 0.04). Moreover, consistent with our maintained hypothesis, the coefficient on corruption in the high-corruption regime is negative and statistically significant, but insignificant in the low-corruption regime.

Once high-income OECD countries are omitted from our sample, the threshold at which corruption adversely affects the quality of roads is 1.6. There are 20 non-OECD countries that fall into this category (Table 5), consisting primarily of high- to upper-middle-income countries. Cyprus, Israel, and South Africa are three examples of countries (within this regime) where some corruption exists, but where road quality is good. Countries at or near the threshold (in either direction)—Hungary, Malaysia, and Tunisia—are a mix of emerging and transitional countries. A large fraction of countries in the high-corruption regime are from sub-Saharan Africa, however this group also consists of transitional countries as well as middle-income emerging countries.

Sensitivity analyses (not shown here) revealed our results to be robust to various specification changes, including additional controls for institutional quality, black market premiums, and country size. Moreover an analysis based on a GMM-estimation procedure suggested by Caner and Hansen (2004) continued to support our underlying conclusions. In Caner and Hansen (2004) the asymptotic arguments are essentially those in Hansen (2000), however, the method for estimating the threshold, τ, is different. The estimation strategy suggested deals with potential endogeneity of left-hand-side variables; however, critically it does not account for endogeneity of the threshold variable. Given our focus on infrastructure quality, our hope was that this would not be much of an issue. While reverse causality would be a problem if we were considering the effect of corruption on broader macroeconomic aggregates, such as the rate of growth, it is not immediately apparent why an unpaved road surface, or "load sharing" and blackouts should have implications for the corruption of public officials. It is nevertheless possible that our measures of infrastructure quality are correlated with other institutional variables, which in turn are correlated with corruption. To some extent we can mitigate this source of bias by introducing controls for development which we have attempted to do. Essentially therefore we have tried to sidestep the issue of endogeneity, rather than dealing with it head-on. This however remains difficult on the basis of existing statistical theory.

5. SOME REMARKS

In this section we make a number of comments with regard to our modeling strategies. In our analysis we assume that governments have complete information over firms' cost structures. This is a departure from the traditional "procurement through bidding" literature which assumes that successful bidders are better informed about their own production costs. While this remains a point of separation between our analysis and this earlier literature, this gap is easily bridged. It is not difficult to extend our model to a situation where the principal (at the outset) has incomplete knowledge about the cost of high-quality inputs. (By contrast, since low-quality inputs (generic) are readily available in the market at competitive prices, costs associated with these inputs are common knowledge.) For example, consider a scenario where there exists a mass of high-quality-input producers. These producers differ according to their costs of production. Though the principal (government) is unable to distinguish (*ex ante*) producers on the basis of their production costs, he has knowledge about the lower bound of the distribution of these costs. Consequently it is optimal for the principal to base contracts on this lower bound in production costs, since such contracts are likely to be taken up by the most efficient producer. Thus, by interpreting c_H as the marginal cost of the most efficient producer, it is possible to adapt our contracting form to include situations where the principal has incomplete knowledge about production costs. However to keep the analysis simple, we do not explicitly consider this scenario in the paper.

Existing data on corruption have a number of shortcomings. These pose at least two hurdles for empirical research. First, existing data on corruption do not distinguish between different types of corruption. Instead corruption measures are typically survey-based indexes that provide some measure of corruption in general. Within the current context a cross-country data set on bribes in public contracting would bridge some of the gap between our theory and empirics. In its absence, the only way forward is through the unheroic assumption that the different forms of corruption are correlated with our aggregate measure. [11] Second, there remain unresolved questions as to the reliability of survey-based measures which are the basis for cross-country data sets on corruption (including the TI index). In particular the reliability of these measures can deteriorate over time, since respondents adjust beliefs as published corruption data become available. [12] Despite these shortcomings corruption measures have exhibited considerable stability over time. Moreover the high correlations between competing measures of corruption provide support for the reliability of survey-based measures (Jain, 2001). In the absence of other viable alternatives we have based our empirical analysis on one of these survey-based indices while being aware of its limitations.

Finally, we recognize that corruption comes in various forms and there are various ways of extracting rents within each category of corruption. Our theory focuses on one particular and important form of bureaucratic corruption in the procurement of goods and services. Corruption in public sector procurement (contracting) plays an important role in determining the quantity and quality of goods and services in many countries. Since the procurement process accounts for nearly 70% (on average) of central government expenditures, we feel that the economic impact of such corruption is significant.

6. CONCLUSION

The view that governance matters have, in recent years, gained increasing acceptability within the development community. Among other things, this has meant an increasing scrutiny of corrupt practices within government bureaucracies. The bases for these new directions in policy making are not uncertain. The evidence that corruption is bad for development is both convincing and robust. As such the conventional wisdom is that corruption should be rooted out wherever and whenever it is found to exist. [13]

However, such a view assumes that the returns to lowering corruption are, at the margin, greater than the costs of doing so. It is far from obvious that this will always be the case. [14] We can therefore reasonably speculate as to the existence of an optimal level of corruption. It is however difficult to say much more without being precise about the nature of anti-corruption technologies.

In this paper our goal is not to confront these issues head-on. Instead our focus has been on developing a better understanding of the costs associated with corruption. We conjecture that the costs of corruption do not increase monotonically, and such costs are only evident when the level of corruption exceeds a certain threshold. We demonstrate that such a hypothesis is both reasonable and consistent with data, and anticipate that such information would prove to be valuable in designing policies to combat corruption in an efficient manner.

NOTES

1. The term "cancer of corruption" was first used by James D. Wolfensohn in his presidential address at the 1996 World Bank/IMF annual meeting.

2. While quality can be allowed to vary continuously over an interval, this generalization would unnecessarily complicate the analysis. Consequently we assume that differences in quality are discrete.

3. In the context of our example, the parameter s_i represents the service value of the public good, for instance s_i could represent its structural quality or the duration the structure remains operational.

4. To keep the story simple, we have not explicitly modeled the possibility that the government will prosecute and penalize firms that cheat. Without loss of generality however we can simply assume that when illegal activities of a firm are revealed, a penalty is imposed which is proportional to the scale of the operation.

5. In theory competition between firms can erode excess profits. In practice, a lack of competition in the procurement process (as well as asymmetric information between the suppliers and the government) creates a potential for positive profits. The existence of these rents create opportunities for corrupt public officials to seek bribes (see Rose-Ackerman, 1975).

6. Bardhan (1997) cites an example in which a highly placed public official in New Delhi reportedly told a friend: "if you want me to move a file faster, I am not sure if I can help you; but if you want me to stop a file I can do it immediately." Bardhan cites the 1964 Santhanam Committee (appointed by the Indian Government) report on the prevention of corruption which notes that corrupt officials actually cause administrative delays in order to attract bribes. In Russia, such activities are commonly referred to as "*mzdoimstvo*," which means to remunerate someone for doing what he was supposed to do anyway. Recent data collected by the World Bank (http://www.doingbusiness.org/) show strong positive correlations between average times to open new businesses and measures of corruption.

7. Such a specification assumes a discontinuity at the threshold, as such it is more general than a continuous spline function which is continuous at $b = \tau$. While methods exist for estimating τ and for approximating the asymstribution of these estimators in either case, the results for discontinuous threshold models do not specialize to the case of continuous linear spline functions (Chan & Tsay, 1998; Hansen, 2000). In fact, the asymptotic distribution of $\hat{\tau}$ is highly non-standard in the discrete case. Here we model threshold behavior by allowing for discrete jumps between regimes because this case imposes less structure on the model.

8. This procedure seems to work best. Certainly we can consider alternative choices for the probability distribution of the random error term, u_i. However Davidson and Flachaire (2001) have shown that when u_i is symmetric the simple 1–0 discrete choice suggested by Wu (1986) works well.

9. This is opposite of the convention of treating higher values as associated with lower levels of corruption.

10. The results are not affected appreciably if corruption is measured in levels. For space considerations, we do not report these (sensitivity) results here.

11. To our knowledge, the only corruption measure that comes close to approximating the "corruption focus" of this study is the Bribe Payers Index (published by Transparency International). This ranks 30 leading exporting countries according to the propensity of domestic firms to offer bribes in their foreign operations. The limited cross-country coverage of this index means that it is not suitable for our analysis. Furthermore, data are available only for the period during 1999–2002.

12. Please refer to Golden and Picci (2005) for an in-depth discussion of this issue.

13. This view has for instance, been articulated by James D. Wolfensohn, former World Bank president. "We are determined to root out fraud and corruption wherever they exist…the Bank continues to be a leader in the fight against corruption, and that we're looking into every allegation we receive related to our work and we are being fully transparent about it."

14. See for instance Acemoglu and Verdier (2000).

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APPENDIX A

Proof of Proposition 1

Let λ_1, λ_2, and λ_3 denote the multipliers associated with the constraints (2a), (2b), and (2c) respectively. Accordingly we write the first order conditions as

$$Q_H : s_H - \lambda_1 p_H + \lambda_2(p_H - c_H) = 0, \quad \text{(A1)}$$

$$p_H : \lambda_1 Q_H = \lambda_2 Q_H + \lambda_3(1 - \phi). \quad \text{(A2)}$$

First note that Eqn. (A1) implies that $\lambda_1 p_H = s_H + \lambda_2(p_H - c_H)$. Since, $p_H \geqslant c_H$ and $\lambda_2 \geqslant 0$, we have $\lambda_1 = 0$. Next, if $\lambda_2 > 0 \Rightarrow (p_H - c_H) = 0$. This would violate the incentive compatibility constraint (2c) as $\frac{\phi}{1-\phi} \geqslant \frac{c_H}{c_H - c_L}$. Accordingly, $\lambda_2 = 0$. Finally, since $\lambda_1 > 0$ and $\lambda_2 = 0$, Eqn. (A2) implies $\lambda_3 > 0$. Given $\lambda_1, \lambda_3 > 0$, the solution (p_H^*, Q_H^*) must satisfy Eqns. (2a) and (2c) taken as equality. This implies $p_H^* = \frac{\phi(c_H - c_L)}{1-\phi}$, and $Q_H^* = \frac{R}{p_H^*}$.

Proof of Proposition 2

(i) First note that, given $\frac{\phi}{1-\phi} \geqslant \frac{c_H}{c_H - c_L}$, a firm's profits are $\pi_H \equiv (p_H^* - c_H)Q_H^* = \frac{\phi(c_H - c_L) - c_H(1-\phi)}{\phi(c_H - c_L)} R > 0$. Next, since red tape is imposed on firms irrespective of what it supplies, the incentive compatibility constraint of firms (Eqn. (2c)) is unaltered. Also, for a given R, the resource constraint of the government (Eqn. (2a)) remains unchanged. However, a bribe, b must now be subtracted from the L.H.S. of Eqn. (2b). This does not, however, alter the first order conditions as given by Eqns. (A1), (A2). Now, let τ be the minimum value of b for which $(p_H^* - c_H)Q_H^* - \tau = 0$. Thus, for any $b < \tau = \pi_H^* = (p_H^* - c_H)Q_H^*$ Eqn. (2b) holds with strict inequality implying that $\lambda_2 = 0$. Since $\lambda_1, \lambda_3 > 0$ is still valid, the solution (p_H^*, Q_H^*) will still be the same as given in Proposition 1.

(ii) To ensure that $\tilde{Q}_H > 0$, the relation $(\tilde{p}_H - c_H)\tilde{Q}_H - b \geqslant 0$ must hold. Since $b > \tau = (p_H^* - c_H)Q_H^*$, it must be that

Table B.1. *Descriptions of variables and data sources*

Variable	Description
Dependent variables	
Quality of electricity	= [100-Electric power transmission and distribution losses (% of total output)]/100. Electric power transmission and distribution losses are technical and non-technical losses this comprises all losses due to transport and distribution of electrical energy and heat, which include losses in transmission between sources of supply and points of distribution and in the distribution to consumers, including pilferage. Estache and Goicoechea (2005), original sources *WB Energy Team*, *World development indicators*.
Quality of roads	= log(length of paved road surfaces). Length of paved road surfaces is calculated as the product of the percent of paved roads and road density, which is the total road network in km divided by the total land area in sq km. Estache and Goicoechea (2005), original sources *International Road Federation*, *World road statistics*.
Quality of water	= Access to improved water sources as a fraction of total population. "Improved" water supply technologies are household connection, public standpipe, borehole, protected dug well, protected spring, rainwater collection. Availability of at least 20 l per person per day from a source within one kilometer of the user's dwelling. "Not improved" are unprotected well, unprotected spring, vendor-provided water, bottled water (based on concerns about the quantity of water supplied, not concerns over the water quality), and tanker–truck-provided water. Estache and Goicoechea (2005), original sources, *World Health Organization*, *United Nations Children's Fund*, JMP report (2004).
Explanatory variables	
Corruption index	= log(10-Corruption perceptions index) Corruption perceptions index is an index of corruption varying between 0 and 10, with higher values corresponding to lower levels of corruption. *Transparency international*.
Initial real GDP	= log real GDP *per capita* in 1990, measures in 1990 dollars. *World development indicators*.
Schooling	= Secondary school enrollment ratio. *World development indicators*.
Population density	= log[population density (people per square km)]. The variable *population density*^{2} is the square of the log of population density. *World development indicators*.
Government balance	= Overall deficit/surplus as % of GDP. *Government finance statistics*.
Trade	= Ratio of exports + imports to GDP. *World development indicators*.

$$(\tilde{p}_H - c_H)\widetilde{Q}_H > (p_H^* - c_H)Q_H^* \Rightarrow c_H(Q_H^* - \widetilde{Q}_H) > (p_H^* Q_H^* - \tilde{p}_H \widetilde{Q}_H) \geqslant 0 \Rightarrow Q_H^* > \widetilde{Q}_H.$$

Further, since $\tilde{p}_H \widetilde{Q}_H = R$, we have $\tilde{p}_H > p_H^*$. Recall that inclusion of bribes leaves the first order conditions (Eqns. (A1) and (A2) unchanged. Since, $\lambda_1 > 0$, Eqn. (A2) implies either ($\lambda_2 > 0$, $\lambda_3 > 0$) or ($\lambda_2 > 0$, $\lambda_3 = 0$) or ($\lambda_2 = 0$, $\lambda_3 > 0$). Since, $\tilde{p}_H > p_H^*$, we have $\lambda_3 = 0$. Therefore, the solution must satisfy λ_1, $\lambda_2 > 0$, and $\lambda_3 = 0$. Accordingly, the solution is given by $\widetilde{Q}_H(b) = \frac{R-b}{c_H}$ implying that $\widetilde{Q}_H$ decreases monotonically with the level of red tape.

APPENDIX B

See Table B.1.