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Procurement Efficiency for Infrastructure Development and Financial Needs Reassessed

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Abstract

Infrastructure is the engine for economic growth. The international donor community has spent about 70–100 billion U.S. dollars on infrastructure development in developing countries every year. However, it is arguable whether these financial resources are used efficiently, particularly whether the current infrastructure procurement prices are appropriate. Without doubt a key is competition to curb public procurement costs. This paper analyzes procurement data from multi and bilateral official development projects in three infrastructure sectors: roads, electricity, and water and sanitation. The findings show that the competition effect is underutilized. To take full advantage of competition, at least seven bidders are needed in the road and water sectors, while three may be enough in the power sector. The paper also shows that not only competition, but also auction design, especially lot division, is crucial for reducing unit costs of infrastructure. Based on the estimated efficient unit costs, the annual financial needs are estimated at approximately 360 billion U.S. dollars. By promoting competition, the developing world might be able to save at most 8.2 percent of total infrastructure development costs.

This paper—a product of the Economics Unit, Finance, Economics and Urban Development Department—is part of a larger effort in the department to understand and investigate efficiency and effectiveness in public infrastructure procurement. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The author may be contacted at aiimi@worldbank.org.

Produced by the Research Support Team

Procurement Efficiency for Infrastructure Development and Financial Needs Reassessed

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I. INTRODUCTION

Infrastructure has been recognized as one of the most important engines for economic growth (e.g., World Bank, 1994). The developing world has received about 70–100 billion U.S. dollars of official development assistance (ODA) a year, of which roughly 12–14 percent has been spent on infrastructure development. Although private financing has been growing in several areas for recent years, the public resources continue to have an important role to play in stimulating and catalyzing infrastructure investment in developing countries.

Public resources deployable for infrastructure are limited in particular in low-income countries. It is essential to ensure that a finite amount of resources should be used most effectively in connection with good governance. The best way to find fiscal space for public investment is to eliminate waste and improve technical efficiency in public expenditure (World Bank, 2005). Efficiency in public procurement has widely been called for more than two decades. However, it is still arguable how the public resources, including foreign aid, can be used more efficiently, particularly where the public procurement systems are fragile.

The current paper, focusing on unit costs of infrastructure, examines to what extent procurement efficiency could be improved for large-scale infrastructure projects assisted by multi- and bi-lateral donors. Particular attention is paid to the effect of intensifying competition at the procurement auction level. In general, the cost of development projects is expected to be reduced, as auctions become more efficient. Our evidence will be supportive of this, but the degree of competition required varies across infrastructure sectors.

Based on the estimated equilibrium bid function, the paper revisits the traditional question of financial needs for infrastructure development in developing countries. As per Fay and Yepes (2003), annual investment needs amount to 470 billion U.S. dollars or 5.5 percent of GDP in developing countries during 2000–10.[1] Unlike the existing literature, the paper will cast light

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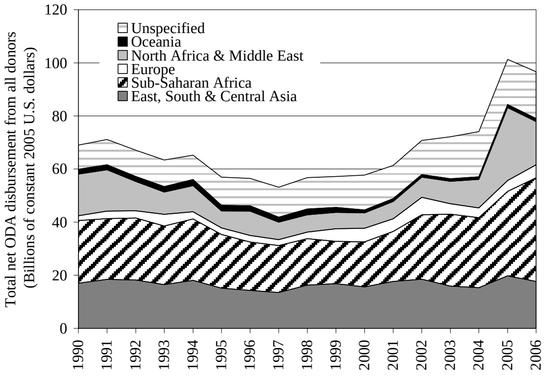
[1] For the road, electricity, water supply and sanitation sectors, the requirement is estimated at 264 billion U.S. dollars per annum.

on the unit price of infrastructure, rather than quantity. Despite the causality issue, it is already agreeable that economic growth necessitates a certain amount of public infrastructure. But it is much less clear whether the current procurement prices of infrastructure are the lowest possible. If they are suboptimal, the total financial requirements could be lowered through improving public procurement efficiency.

Official development assistance has continued to be sizable and has picked up in the last three years (e.g., OECD, 2007). In 2006 the international donor community—including not only OECD member countries but all donors—disbursed about 100 billion U.S. dollars, of which Development Assistance Committee (DAC) countries contributed to roughly 95 percent. Assistance efforts are increasingly concentrated on North Africa and Sub-Saharan Africa (Figure 1). By sector, total official assistance from DAC member states for infrastructure development—defined as the energy, transport, communications, water supply and sanitation sectors in the current paper—amounted to 12 billion U.S. dollars, which is equal to 12 percent of total net ODA (Figure 2).[2] This represents about 0.1–0.2 percent of total GDP of developing countries. From the donor point of view, it is equivalent to 0.03–0.04 percent of total GDP of OECD countries. However, this amount is far below the recent demand forecast, e.g., 470 billion U.S. dollars pointed out above.

Figure 1. Net ODA Disbursement by Region



Source: OECD.Stat Extracts.

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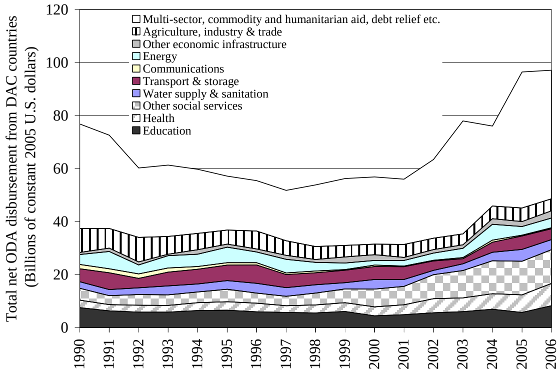
[2] The water supply and sanitation sector is usually classified under the “social infrastructure and services” category, instead of “economic infrastructure,” which includes energy, communications and transport.

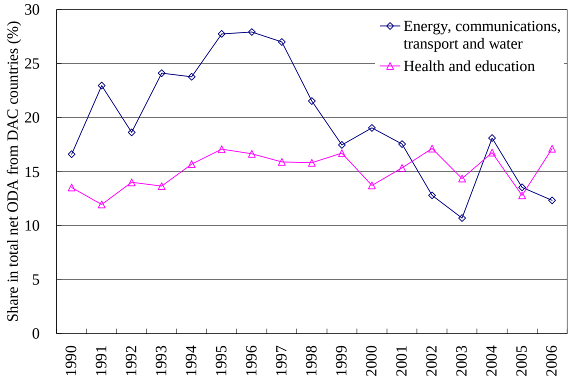
Figure 2. Net ODA Disbursement from DAC Countries by Sector



Source: OECD.Stat Extracts.

Regardless of the continued importance of and donors' recent efforts toward infrastructure assistance, the allocation to infrastructure, including water and sanitation, appears stagnant with a peak of the sectoral share in 1996 (Figure 3). The allocation to the social sector, such as health and education, continues much stable at about 15 percent. On the other hand, the infrastructure sector amounted to over 25 percent in the mid-1990s but dramatically declined to less than 15 percent by 2003. Energy and communications are two areas where official assistance faded out. Obviously, some of investments in these sectors—and transport to a lesser extent—were replaced with private financing.

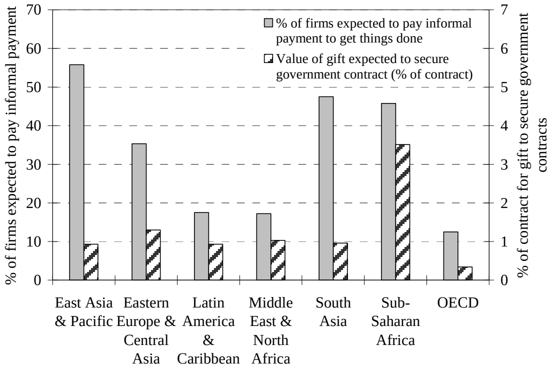
Figure 3. Sectoral Share in Total Net ODA Disbursement from DAC Countries



Source: OECD.Stat Extracts.

Unfortunately, however, there are many pieces of anecdotal evidence indicating that these resources might be wasted through the public procurement systems. For instance, a series of enterprise surveys reveal that informal payments are a common practice all over the world. In developing countries, firms are paying approximately as much as 1 percent of the contract amount to secure government purchases. In Sub-Saharan Africa, this reaches 3½ percent on average (Figure 4). Anti-Corruption Coalition Uganda reports that the country is losing about 1.5 percent of GDP a year due to corruption in public procurements (MS, 2005). Since the Uruguay Round conclusion in 1996, WTO has taken a lead to strengthen the Government Procurement Agreement (GPA), which requires member states to establish an open, transparent and nondiscriminatory procurement process for government procurements above the agreed thresholds. In 2007 the World Bank approved the Implementation Plan of Governance and Anticorruption (GAC) strategy, which aims to strengthen anticorruption processes at various levels.

Figure 4. Informal Payment Practices in Developing Countries



Source: Enterprise Surveys.

Then, a key policy question is how to improve efficiency in the public procurement systems. Unsurprisingly, competition for contracts is an essential factor, because governments do not know the underlying true project costs of private contractors. This is a fundamental asymmetric information problem that auctioneers must overcome when they aim to contract out a public service. The authorities may know their own costs, which are presumably too high compared with private costs. They may also be able to observe some pieces of “market-based” engineering costs. But they never know the minimum possible project cost in the market. If they knew, they could negotiate and contract directly with the most efficient firm. Auction theory tells us that under standard circumstances intensifying competition at an auction would induce bidding firms to reveal their true preferences—i.e., costs in our context—whence achieving efficient auction outcomes (e.g., Brannman, *et al.*, 1987; Paarsch, 1992).

In large-scale infrastructure projects, an alleged concern is the limited competition among firms that repeatedly participate in the procurement process. Foster (2005) highlights this problem in the water-sector concession context, showing that at the most six firms have been applying for a series of auctions in Latin America. Whether or not to succeed in attracting a sufficient number of competitors is indeed a crucial determinant of efficiency in auction outcomes, as well demonstrated in the 3G mobile telecommunications experiences in Europe (e.g., Klemperer, 2002; van Damme, 2002; Seifert and Ehrhart, 2005).

What are the benefits from intensified competition? First, it is expected to not only lead to economic efficiency but also prevent corruption and collusion. In theory, it becomes more difficult to agree on and sustain a collusive arrangement, as the number of potential players in a market increases. Particularly it is true when new entrants are involved. A nontrivial probability of not being awarded would significantly weaken bidders' collusive incentive (e.g., Bresnahan and Reiss, 1991; Che and Kim, 2006). If competition makes collusion less likely to occur, the risk of corruption is also alleviated because corruption normally necessitates successful collusion among bidders.[3]

Notably, public procurements for infrastructure projects are normally sizable. The large contract amount will easily induce stakeholders involved—e.g., politicians, civil servants, contractors and even beneficiaries—to explicitly and implicitly collude with each other; the lure of enormous payoffs would be irresistible, regardless of a potential penalty if detected. If

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[3] Without binding collusive arrangement, corruption cannot be in effect for securing a target contract, because firms outside the collusive agreement may submit a better bid, breaking a prior agreement among collusive bidders. Hence, the incentive to engage in corrupt practices must be weakened under less collusive circumstances. However, if informal payment is so common and all bidders pay bribe to an auctioneer, auction theory may fail to expect the anticorruption effect from increased competition. This is because in a symmetric equilibrium, a shift of bidders' underlying cost parameters caused by this bribe would just be added t oall bidders' bids.

the above-mentioned enterprise survey result is directly applied to the recent aid figure, it means that 100–400 million U.S. dollars might be wasted for informal payments. Furthermore, when dead-weight losses are taken into account, the total economic cost may be 1.2 to 2.9 times higher than the amount of bribes paid (Auriol, 2006).

Second, strengthening competition in public procurement would be conducive to fostering good governance and market-oriented business environment in developing countries. Good governance is essential for economic growth, and many developing countries are wasting abundant resources for a variety of informal business practices, such as bribes and misappropriations.[4] Francisco and Pontara (2007), estimating the bribe propensity of firms in Mauritania, show that medium-sized enterprises remains relatively weak and thus tend to rely on bribery for expanding their business, which is in turn hindering the country's private sector development. Olken (2005) shows that resource misuse reaches 20–30 percent of total (disbursed) costs in public road projects and that auditing by a central government agency has a positive impact on reducing such misuse.

Auction-based procurement systems are inherently transparent, open, accountable, credible and nondiscriminatory, while mutual transactions involving a small number of players tend to be less transparent and more susceptible to collusion and corruption (Krishna, 2002; Boehm and Olaya, 2006). Transparent and efficient business practices in improved public procurement systems would have positive externalities on local private business behavior, raising competitiveness of the economy as a whole. Not surprisingly, there is a strong correlation between pervasive informal payment practices and side payments for public contracts, as shown in Figure 5. It depicts such a cross-country correlation from enterprise surveys in about 100 countries.

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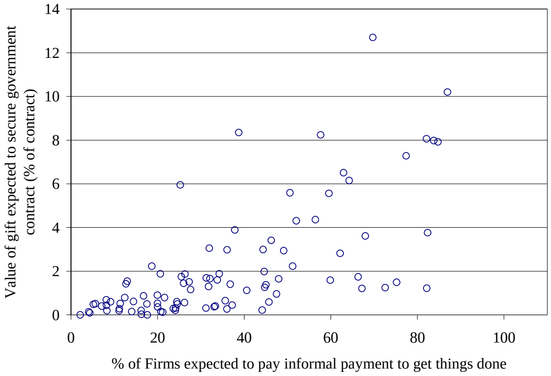
[4] There is a debate on whether good governance could contribute to economic growth at the aggregate level (Burnside and Dollar, 2000; Easterly, et al., 2004).

Figure 5. General Informal Payment Practices and Corruption in Public Procurements



Source: Enterprise Surveys.

Finally, high efficiency caused by intense competition has positive impacts on recipient macroeconomies. It directly creates local business opportunities if local firms are involved in ODA projects. It also mitigates the Dutch disease syndrome associated with massive aid flows. If development projects are financed by official external borrowings, it is also conducive to alleviating national burdens of external debt repayments and servicing. From the aid donor point of view, high efficiency means that more development projects and programs could be supported by a fixed amount of aid money (Iimi, 2006).

This paper empirically readdresses the question of whether the public infrastructure spending is efficient, focusing on the procurement unit costs. It will be estimated how many bidders are required for an auction to be competitive enough in each of the road, water and sanitation, and electricity sectors. Based on the estimated competition effect, the paper also calculates how much competition could contribute to improving efficiency in infrastructure procurements. The findings would demonstrate practical gains from strengthening public expenditure management and support the governance-growth linkage numerically.

The remaining sections are organized as follows. Section II reviews the existing literature on the competition effect in auctions. Section III describes our empirical model and data for estimating a conventional equilibrium bid function. Section IV summarizes the main estimation results. Section V discusses several policy implications. It attempts to refine the financial needs for infrastructure development based on our estimated efficient project prices.

The section also touches upon the importance of unobservable country-specific characteristics, such as a well-known unobserved "Africa-specific" fixed-effect.

II. COMPETITION IN AUCTIONS: LITERATURE REVIEW

The main objective of government purchase is to deliver the object or public services at the lowest costs with a reasonable level of quality. Auction theory suggests that the winning bid should tend to approach the lowest possible procurement price, as the number of participants in an auction increases. This proposition holds typically in the independent private value paradigm. Even in the common value paradigm, the positive competition effect may be expected to a certain extent (Paarsch, 1992). Of particular note, in the common value auctions the equilibrium bid may also increase with the number of bidders, because the risk of overestimating the true value of the object tends to increase as competition becomes more intense (e.g., Kagel and Levin, 1986).

An important policy question is how many bidders are required for an auction to be competitive enough. It varies from sector to sector, depending on the nature of the objects to be sold (Table 1). In the infrastructure sector, the norm might be about eight firms.[5] The highway construction market (in Florida) becomes competitive with about six to eight bidders (Gupta, 2002). As per Iimi (2006), in ODA-related procurement auctions mainly for large social and infrastructure projects, the winning bid amount significantly decreases as the number of bidders rises to the level of about eight firms. In the U.S. offshore oil lease market, the similar level of bidder participation seems to be required (Brannman *et al*., 1987).

In government procurement for forest-related services, a slightly smaller number of contenders—perhaps five—are needed for auction efficiency. Brannman *et al*. (1987) shows that 4–5 bidders are necessary for the timber seeding service contracts in the Pacific

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[5] It means that the marginal impact of one more bidder on the equilibrium bid is not statistically significant when the number of participants exceeds eight.

Northwest. In the case of plant seedling auctions, Paarsch (1992) indicates that although the timber seedling auctions are likely to be characterized as the common value paradigm, the expected winning bid would decline until the number of participants reaches roughly 5 to 10.

By contrast, in the Internet-based auction, eBay, for a personal digital assistants device, the observed bid price tends to continue increasing with the number of bidders beyond the above-mentioned levels; the incremental effect would taper off only when more than 14 bidders participate. Under the experimental setting, Kagel and Levin (1986) show that bidders tend to submit relatively aggressive bids in auctions with 6–7 participants, compared with the case with 3–4 bidders.

Table 1. Competition Effects in Various Auctions

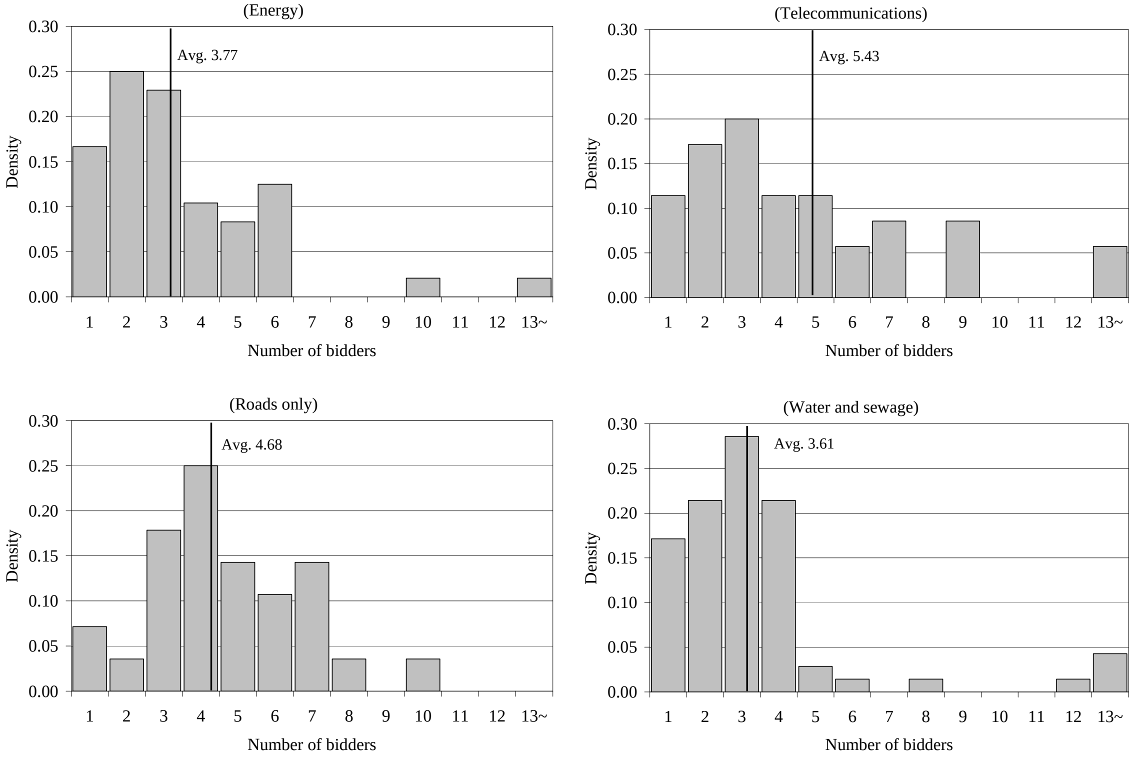
Study	Type of contract	Est. optimal no. of bidders	No. of observations
Brannman *et al*. (1987)	U.S. municipal bond underwriters spreads in 1959-67.	5–8	9,420
	U.S. offshore oil lease auctions from 1954 to 1975.	7–9	2,211
	U.S. National Forest Service timber auctions in 1977.	4–5	639
Paarsch (1992)	British Columbia's plant seedling contract auctions between 1985-88.	About 5	144
Gupta (2002)	Highway construction procurement auctions in Florida from 1981 to 1986.	6–8	1,937
Rezende (2005)	Palm III personal digital assistants auctions at eBay in Oct-Nov, 2000.	About more than 14	2,299
Iimi (2006)	Large-scale official development projects, largely in the infrastructure sector, assisted by Japan for1999-2005.	8	922

Source: Author’s calculations from the original studies.

As far as infrastructure projects are concerned, the observed level of competition is less than the general norm—e.g., eight. Iimi (2006) indicates that in Japan’s ODA procurement, the average number of bidders is about six. In the U.K. PFI projects, half of them attracted at most two or three bids prior to 2004 (NOA, 2007). In 2005-06, this share increased to as high as 80 percent; more than 30 percent of the PFI projects were competed for by only two bidders. Similarly, PPI database reveals that no more than five firms participate in bidding competition for PPP transactions in developing countries (Figure 6).

Even in the infrastructure sector, the number of firms who participate in each auction differs across sub-sectors. While the distributions of the number of bidders in road and telecommunications PPP contracts are not so concentrated, the energy sector has a more skewed distribution toward a left tail. In the water sector one can expect only one to three bidders in most cases.[6]

Figure 6. Degree of Competition in PPP Auctions



Source: Author's calculation based on PPI database.

The current paper pays particular attention to this difference across infrastructure sectors, which *is* ignored in the previous work (Iimi, 2006). An obvious disadvantage of focusing on a certain sub-sector is the small sample problem. This is related to a more fundamental empirical question that researchers must consider. One might think that all development

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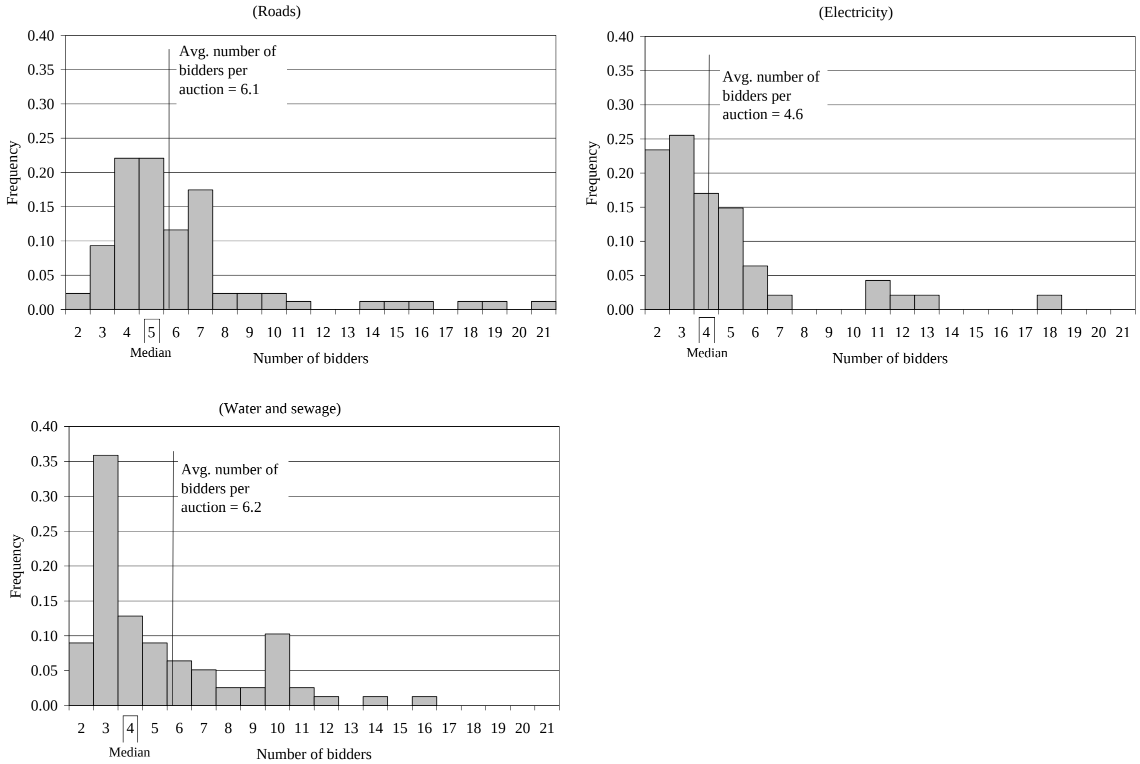
[6] Recall that these PPP contracts are not only for infrastructure construction, on which our sample projects focus. Rather, they normally include operation and maintenance after construction and thus tend to require more managerial and operational expertise from contractors. Therefore, the observed degree of competition in PPP auctions may not be directly comparable with our results.

projects—particularly large-scale national projects—are different and unique. To compromise this problem, three main infrastructure sectors are selected in this paper: roads, electricity, and water and sanitation. Our sample data partly overlap with my previous work, which cover large ODA projects assisted by the Japanese Government. But the more detailed contract-specific information has been added. The current paper also uses a new dataset on broadly similar infrastructure projects financed by the World Bank.

As expected, our sample reveals that the degree of procurement competition appears to differ among sectors (Figure 7). In road procurements, one can expect a number of competitors per auction—averaging 6.1 firms. The probability of attracting more than six firms to competitive bidding is considerable. By contrast, competition seems much limited in the other two sectors. It is consistent with the above PPP contract cases. In the water and sewage sector, the average number of bidders per auction is 6.2, but the distribution highly concentrates on $N=3$; the median is 4. In the electricity sector, most auctions have attracted two or three firms. Formally, the extent to which competition takes effect is lowest in this area. The skewness is estimated at 2.02, which is higher than 0.63 in the water sector.

The above is naturally followed by the question of how many bidders are required to enhance auction efficiency in each of the infrastructure sectors. It seems that in electricity projects one cannot expect the same level of competition as road procurements. In addition, it is also debatable whether the current level of competition in the electricity sector is really sufficient to maximize the competition effect. If not, what can we do? The following sections address these questions by estimating an equilibrium bid function.

Figure 7. Degree of Competition in Infrastructure ODA Procurements



Source: Author's calculation based on JBIC and World Bank data.

III. AN EMPIRICAL MODEL AND DATA

Following the existing empirical auction literature (e.g., Porter and Zona, 1993; Gupta, 2002; Iimi, 2006), the following reduced-form equilibrium bid function is estimated:

$$b_{it} = COST_t\alpha_1 + MONTH_t\alpha_2 + X'_t\,\beta + Z'_i\,\gamma + g(N_t;\delta) + \varepsilon_{it}$$

where b_{it} is i's bid amount at auction t. It is noteworthy that our dependent variable is the bid amount of all bidders, i.e., both winning and losing bidders. Note that in theory losing bids are as informative as winning bids to estimate the equilibrium bid function. The ODA-related procurement process normally uses a simple first-bid sealed-price auction format. Therefore, all bidders equally have the incentive to submit their true equilibrium bid prices calculated based on their private information.

N is the number of bidders who were prequalified (if applicable) and actually participated in the price competition. In our data, this variable is usually common knowledge prior to the bidding stage; in most cases, in practice, participants know how many rivals would submit bids, especially when the prequalification result is published.[7] The endogeneity of *N* is one of the important questions in the empirical auction literature (e.g., Li and Perrigne, 2003; Ohashi, 2008; Bajari., *et al*, forthcoming). With our data, a truncated negative binomial model has shown that almost none of the major contract attributes, such as estimated engineering costs, contract duration and technical evaluation practices, and potential ODA project backlogs, are significant in explaining the observed number of participants.[8] Similarly, it has been found that the instrumental variable (IV) estimation with these variables as instruments would not significantly change the main results presented below, possibly supporting the exogenous nature of our *N* definition.

It is also noteworthy that our analytical framework is very static; *N* is irrelevant to how many firms constitute a bidding entity. Joint bidding practices are already given in our model. Potential bidders, who shown interest but did not participate in the process, are also ignored. But this setting is consistent with basic auction theory. Regarding the functional form for the competition effect, no presumption is imposed; we examine four specifications: linear, quadratic, log-linear and (partially) nonparametric.

Two auction-specific variables are included for all sectors: engineering lot cost estimate (*COST*) and expected contract duration (*MONTH*). X_t is a vector of other observable technical attributes that are characteristic of each sector. These variables are also auction-

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[7] The majority of our sample auctions adopted the prequalification procedure. For instance, more than 90 percent of road procurements used prequalification.

[8] There is only one significant coefficient, which is associated with the prequalification dummy variable in the case of electricity projects. This potentially affects the measured competition effect and may cause our unstable estimation result in this sector, as shown below. See Iimi (2008) for further details.

specific and expected to reflect the average project value for bidders. For road contracts, the total length of roads to be constructed and/or rehabilitated and the number of lanes of those roads are included. The type of work is also distinguished by new construction, rehabilitation and upgrading. For electricity contracts, the size of installed capacity in MW and the capacity of transmission lines—in terms of both voltage (kV) and length (km)—are measured. For the water- and sewage-sector contracts, similarly, the proxies of treatment capacity (million m^3 per day) and total network length (km) are introduced to control for heterogeneity across projects.

Since two sets of project data assisted by different organizations are merged, the donor dummy variable is supposed to capture the systematic difference in selected projects.[9] Finally, the project location dummy variables are also included in X_t.

Our (dis)aggregation is still imperfect in the sense that different types of components are pooled together, especially in the electricity and water sectors. However, one advantage of our data treatment is that we can remain sufficient observations, whence ensuring robustness of estimates.

We are also allowed to infer the cost of an "average" infrastructure contract by pooling various but necessary components in each sector. Technically, we will evaluate the estimated bid function at the mean values of variables included. Any infrastructure project is a complex compound made up of various elements. This is an inherent and important feature of infrastructure projects. From the practitioner point of view, it is of little interest how much a specific type of equipment—for instance, a power generating turbine—costs. Such information may be publicly available on a list of manufacturing prices. Instead, an important

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[9] In fact, the two data are different. In our sample, first, the Japanese aid data concentrates on 5–6 East and Southeast Asian countries. On the other hand, the World Bank data cover the rest of the world, such as Middle East and Africa. This is our "intended" selection bias to cover the whole developing world. Second, the Japanese data are only available for the contract amount greater than one billion Japanese yen (roughly 9 million U.S. dollars). The World Bank data includes many small contracts, which may be less than 1 million U.S. dollars. Hence, the donor dummy variable may capture such systematic differences in projects and contracts assisted by the two donors.

policy question is how much it costs to procure a package of necessary equipment, civil works and facilities to supply 100 kWh to people. It must be composed of generators, transmission and distribution lines, dispatch systems and other facilities. Another example is this: Some procurement packages aim to purchase both generation turbines and transmission lines, and others not. In some cases, both water treatment plant construction and treated water distribution pipe installation were contracted out together, but in other cases they are procured separately. Then, how much does a "standard" contract package for the electricity or water system? By not disaggregating data, we can answer this question.

Z_i is a set of bidder-specific attributes. To control bidder heterogeneity, bidder nationalities are included in Z_i. Firms from different countries naturally have different cost advantages. Local firms registered in a project host country may have better informational and physical access to local markets than foreign companies. Local firms may also have better knowledge of local administration and public administration. On the other hand, foreign firms may be more familiar with advanced technologies and have an accumulation of similar development projects.

Our data cover 211 procurement auctions for infrastructure development projects in 29 developing countries from 1997 to 2007. In total, 862 winning and losing bids are observed. The road, electricity and water sectors attracted 394, 193 and 329 bids, respectively. Table 2 summarizes our data coverage in terms of country and sector.

It is by no means comprehensive. First of all, our sample covers only 5 percent of total ODA in infrastructure. The total amount of contracts in our sample is about 6 billion U.S. dollars, which are distributed over the last decade or so. Total official assistance for infrastructure development amounts to US$ 12 billion a year.

Second, the country coverage is narrow and partial. China's projects are dominant. Road projects concentrate on three East Asian countries: China, the Philippines and Vietnam. The country coverage for water and sewage projects may be relatively broad, including Iran, Mexico, and Thailand. But it is not random selection but subject to data availability. In the electricity sector, the total number of contracts collected is much smaller than the other two sectors, with a high concentration on China and Vietnam. With relatively limited participation per auction in this sector, the number of observed bids is even more limited. This may raise an empirical problem of robustness in the following analysis.

Table 2. Sample Coverage

	Roads		Water & sewage		Electricity	
	No. of auctions	No. of bidders	No. of auctions	No. of bidders	No. of auctions	No. of bidders
Albania					1	4
Azerbaijan					2	5
China	21	103	24	106	15	43
Congo, Republic of	3	9				
Croatia			4	20		
Egypt					2	8
Ethiopia	7	32				
Ghana	4	12				
India			5	11	1	3
Indonesia					3	3
Iran			7	41		
Kazakhstan	2	7	1	2		
Kenya					3	14
Lebanon			2	2		
Malaysia					2	2
Mexico			9	31		
Morocco			1	6		
Nigeria					2	11
Peru	3	16	4	16		
Philippines	12	36				
Sri Lanka	3	7	1	2	1	3
Swaziland	1	4				
Tanzania	2	11	4	12	4	13
Thailand	8	56	9	57		
Turkey	2	34				
Uganda					2	3
Viet Nam	11	51	3	7	9	27
Yemen			4	16		
Zambia	7	16				
Total	86	394	78	329	47	139

Source: Author's calculation.

The summary statistics are shown in Table 3. The average bid amount for road projects is 29 million U.S. dollars. While the average for water contracts is much smaller at 15 million U.S. dollar, the average bid amount in the electricity sector is largest at 49 million U.S. dollars. The engineering cost estimates are consistent with these figures. The contract duration is normally more than two years but with a wide range from 3 months to 6 years.

On the technical side, the average length of road contract is 49 km. New road construction works amount to 35 percent of our road sample, and rehabilitation works amount to 30 percent. In the water and sewage sector, the average treatment capacity, if the work is to construct water and waste water plants, is 0.08 million m^3 per day. A pipe installation work involves about 33 km of iron pipes on average.[10] Half the contracts are related to the water supply sector. Note that a single contract sometimes covers both water supply and sewage works. While one-third are related to treatment plant construction, two-thirds aim at developing water distribution and collection networks. The electricity sector is most complicated, covering many different elements. The average installed capacity is 118 MW in our sample. If a contract includes transmission line installation, the "average" description may be 51 km of 43 kV lines.

Table 3. Summary Statistics

	Obs	Mean	Std. Dev.	Min	Max
Roads					
Bid amount (million US$)	394	29.40	28.57	0.28	161.22
Number of bidders	394	8.02	5.27	2	21
Total road length (km)	394	48.97	65.85	2.24	448.00
Number of lanes	394	2.87	1.78	1	8
$D_{\text{(New roads)}}$	394	0.35	0.48	0	1
$D_{\text{(Rehabilitation work)}}$	394	0.29	0.45	0	1
Cost estimate (million US$)	394	34.21	38.36	0.28	145.99
Contract duration (month)	394	31.61	11.75	5.00	50.00
Water and sewage					
Bid amount (million US$)	329	15.00	23.13	0.33	276.66
Number of bidders	329	6.67	3.62	2	16
$D_{\text{(Water)}}$	329	0.44	0.50	0	1
$D_{\text{(Treatment plant)}}$	329	0.35	0.48	0	1
$D_{\text{(Network)}}$	329	0.64	0.48	0	1
Treatment capacity (million m3)	329	0.08	0.16	0.00	0.60
Total concrete tunnel length (km)	329	0.97	3.78	0.00	24.85
Total iron pipe length (km)	329	33.21	59.62	0.00	375.58
Cost estimate (million US$)	329	13.74	16.85	0.33	154.26
Contract duration (month)	329	28.23	16.66	3.00	72.00
Electricity					
Bid amount (million US$)	139	49.06	71.96	0.22	435.49
Number of bidders	139	5.32	3.62	2	18
$D_{\text{(Dam)}}$	139	0.09	0.29	0	1
$D_{\text{(Generator)}}$	139	0.30	0.46	0	1
$D_{\text{(Trans. lines)}}$	139	0.26	0.44	0	1
$D_{\text{(Substation)}}$	139	0.26	0.44	0	1
$D_{\text{(Civil work)}}$	139	0.65	0.48	0	1
Installed capacity (MW)	139	118.74	277.71	0.00	1200.00
Number of generators	139	1.37	2.78	0.00	12.00
Transmission line capacity (kV)	139	43.54	119.96	0.00	500.00
Total transmission line length (km)	139	50.58	149.22	0.00	765.00
Cost estimate (million US$)	139	44.27	66.69	0.25	406.61
Contract duration (month)	139	28.42	13.52	3.00	66.00

Source: Author's calculation.

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[10] These figures are underestimated, because both treatment plant and network contracts are pooled in our model. If a contract involves either component, the other capacity measurement is set at zero.

IV. ESTIMATION RESULTS AND IMPLICATIONS

Two models are examined in each sector. The first specification involves the engineering lot cost estimate as one of the independent variables; the second does not. An advantage of including the cost estimate variable is to improve accuracy in estimates, because it can control for unobservable technical heterogeneity across contracts. It is certain that many technical aspects are potentially omitted in our model. But all of them are expected to be reflected in a single monetary measurement, i.e., engineering cost estimate. Indeed, this variable has been found very powerful to explain the submitted bids, though not necessarily close to unity.[11] The coefficient is estimated at about 0.53 in road projects, meaning that the engineering cost is systematically overestimated by more than 40 percent (Table 4). The coefficient for water-related contracts is about 0.8, which can be similarly interpreted as a systematic overestimation (Table 5). In the electricity sector, on the other hand, the coefficient is estimated at 1.2 (Table 6). This may raise concern about underestimation and the consequence of cost overruns.

The expected duration of project contracts has been found a weak explanatory variable, particularly when the engineering cost variable is included. This is partly because of high colinearity. In the road sector, for instance, the simple correlation coefficient is about 0.7.

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[11] The engineering cost estimates adopted in the paper are calculated by donors for project appraisal purposes. They may not necessarily reflect the best information at time of actual procurement. Moreover, they are not relevant to auctioneers' reservation prices. For these reasons, our engineering estimates may be systematically biased due to donors' calculation methods.

Table 4. Estimated Equilibrium Bid Function: Road Sector

	Linear	Quadratic	Log-linear	Non-parametric	Linear	Quadratic	Log-linear	Non-parametric
N	-0.52 ***	-0.12			-1.00 ***	-1.61 **		
	(0.09)	(0.63)			(0.11)	(0.81)		
N^2		-0.02				0.03		
		(0.03)				(0.04)		
$\ln(N)$			-4.82 ***				-9.50 ***	
			(0.88)				(1.23)	
$N=2$				8.57 **				8.86 *
				(3.39)				(4.64)
$N=3$				6.54 **				16.93 ***
				(2.92)				(3.93)
$N=4$				6.37 ***				13.00 ***
				(1.98)				(2.29)
$N=5$				2.45 *				8.76 ***
				(1.40)				(1.81)
$N=6$				2.94 **				2.06
				(1.24)				(1.82)
$N=7$				1.39				5.45 ***
				(1.50)				(1.66)
$N=8$				-0.53				9.24 **
				(2.41)				(3.89)
$N=9$				2.31				10.11 ***
				(2.29)				(3.07)
$N=10$				4.56 ***				3.09 **
				(1.57)				(1.38)
$N=11$				0.14				-6.03
				(4.56)				(6.34)
Length	0.12	0.12	0.11	0.12	0.25 ***	0.24 ***	0.23 ***	0.29 ***
	(0.08)	(0.08)	(0.08)	(0.08)	(0.09)	(0.09)	(0.09)	(0.09)
Length^2 1/	-0.41	-0.41	-0.39	-0.43	-0.65	-0.64	-0.61	-0.75
	(0.40)	(0.40)	(0.40)	(0.43)	(0.45)	(0.45)	(0.45)	(0.47)
Lane	12.57 ***	12.15 ***	12.98 ***	12.74 ***	14.62 ***	15.23 ***	15.58 ***	15.94 ***
	(1.86)	(2.04)	(1.97)	(2.27)	(2.12)	(2.41)	(2.27)	(2.57)
Lane^2	-1.10 ***	-1.06 ***	-1.13 ***	-1.10 ***	-1.22 ***	-1.28 ***	-1.31 ***	-1.30 ***
	(0.17)	(0.19)	(0.18)	(0.21)	(0.19)	(0.22)	(0.21)	(0.25)
$D_{\text{(New roads)}}$	4.23	4.50	3.76	3.06	10.49 ***	9.99 **	9.28 **	7.56 *
	(3.17)	(3.17)	(3.18)	(3.40)	(4.02)	(4.13)	(4.05)	(4.12)
$D_{\text{(Rehabilitation work)}}$	1.67	2.02	1.16	1.14	-0.65	-1.15	-1.72	-4.59
	(2.14)	(2.19)	(2.16)	(2.62)	(3.18)	(3.38)	(3.24)	(3.50)
Engineering cost	0.53 ***	0.53 ***	0.52 ***	0.54 ***				
	(0.04)	(0.04)	(0.04)	(0.05)				
Estimated duration	-0.30 ***	-0.29 ***	-0.31 ***	-0.25 ***	-0.09	-0.11	-0.12	-0.04
	(0.07)	(0.07)	(0.08)	(0.08)	(0.08)	(0.09)	(0.09)	(0.11)
Donor 1	-6.48 **	-6.68 **	-6.13 **	-7.27 **	-6.06 *	-5.76	-5.35	-1.82
	(2.58)	(2.65)	(2.53)	(3.22)	(3.69)	(3.79)	(3.67)	(4.00)
Constant	-1.67	-3.14	3.25	-9.71	-4.95	-2.66	5.27	-27.25 ***
	(4.50)	(4.43)	(4.40)	(5.75)	(6.13)	(6.27)	(6.10)	(6.80)
Obs.	394	394	394	394	394	394	394	394
R-squared	0.932	0.932	0.932	0.933	0.903	0.903	0.905	0.909
Number of dummies								
Country	11	11	11	11	11	11	11	11
Bidder nationality	19	19	19	19	19	19	19	19

1/ For presentation purposes, the coefficients are multiplied by 1,000.

Note: The dependent variable is the bidding amount. The robust standard errors are shown in parentheses. *, ** and *** indicate the 10%, 5% and 1% significance levels, respectively.

Source: Author’s calculation.

Table 5. Estimated Equilibrium Bid Function: Water Supply and Sewage Sector

	Linear	Quadratic	Log-linear	Non-parametric	Linear	Quadratic	Log-linear	Non-parametric
N	-0.08	-0.18			-0.49 ***	-1.55 ***		
	(0.08)	(0.34)			(0.13)	(0.49)		
N^2		0.01				0.06 **		
		(0.02)				(0.02)		
ln(*N*)			-0.42				-3.26 ***	
			(0.59)				(0.92)	
N=2				-0.88				-4.79
				(2.01)				(4.67)
N=3				0.04				5.06 ***
				(0.85)				(1.56)
N=4				0.77				5.12 ***
				(1.02)				(1.95)
N=5				-0.68				3.44 **
				(1.27)				(1.66)
N=6				2.64 **				3.62 **
				(1.33)				(1.63)
N=7				1.33 *				-1.01
				(0.78)				(1.47)
N=8				1.66 **				-3.64 **
				(0.72)				(1.50)
N=9				-3.05 **				3.43 *
				(1.42)				(1.86)
$D_{\text{(Water)}}$	0.95	0.93	0.94	1.01	1.76	1.52	1.68	1.71
	(1.65)	(1.66)	(1.65)	(1.66)	(2.38)	(2.35)	(2.38)	(2.56)
$D_{\text{(Treatment plant)}}$	1.29	0.79	1.48	1.83	-57.83 ***	-62.51 ***	-59.33 ***	-56.03 ***
	(6.88)	(7.31)	(7.10)	(7.61)	(14.31)	(14.68)	(14.42)	(17.14)
$D_{\text{(Network)}}$	5.31	5.27	5.38	5.90	-10.50 **	-10.73 **	-10.33 **	-12.20 **
	(3.48)	(3.52)	(3.48)	(3.81)	(5.10)	(5.12)	(5.12)	(5.09)
ln(*Treatment capacity*)	0.23	0.28	0.22	0.11	5.28 ***	5.67 ***	5.42 ***	5.04 ***
	(0.55)	(0.59)	(0.57)	(0.61)	(1.25)	(1.30)	(1.27)	(1.35)
ln(*Concrete tunnel length*)	-0.17 *	-0.17	-0.18 *	-0.27 **	0.58 ***	0.61 ***	0.58 ***	0.69 ***
	(0.10)	(0.11)	(0.10)	(0.11)	(0.17)	(0.17)	(0.17)	(0.19)
ln(*Iron pipeline length*)	-0.13	-0.12	-0.13	-0.19	0.92 ***	0.95 ***	0.92 ***	0.99 ***
	(0.13)	(0.14)	(0.14)	(0.16)	(0.21)	(0.21)	(0.21)	(0.22)
Engineering cost	0.79 ***	0.78 ***	0.79 ***	0.81 ***				
	(0.06)	(0.06)	(0.06)	(0.07)				
Estimated duration	-0.10 **	-0.09 **	-0.10 **	-0.10 *	0.08	0.10	0.10	0.04
	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)	(0.06)	(0.07)
Donor 1	137.70 ***	1.07	1.01	-1.42	31.48 ***	29.99 ***	29.28 ***	21.56 ***
	(14.87)	(2.25)	(2.25)	(8.16)	(8.62)	(9.02)	(8.95)	(7.94)
Constant	-3.69	-3.03	-4.43	-7.91	111.28 ***	122.98 ***	117.58 ***	107.95 ***
	(10.68)	(14.32)	(13.83)	(11.11)	(21.93)	(21.47)	(20.69)	(25.30)
Obs.	329	329	329	329	329	329	329	329
R-squared	0.964	0.964	0.964	0.966	0.907	0.908	0.907	0.916
Number of dummies								
Country	12	12	12	12	12	12	12	12
Bidder nationality	20	20	20	20	20	20	20	20

Note: The dependent variable is the bidding amount. The robust standard errors are shown in parentheses. *, ** and *** indicate the 10%, 5% and 1% significance levels, respectively.

Source: Author’s calculation.

Table 6. Estimated Equilibrium Bid Function: Electricity Sector

	Linear	Quadratic	Log-linear	Non-parametric	Linear	Quadratic	Log-linear	Non-parametric
N	-3.03 ***	-8.02 *			-3.61	-9.74		
	(0.99)	(4.71)			(2.96)	(10.58)		
N^2		0.36				0.44		
		(0.31)				(0.71)		
$\ln(N)$			-19.53 ***				-23.78	
			(6.13)				(16.90)	
$N=2$				20.26 **				2.64
				(8.18)				(26.72)
$N=3$				6.91				-10.37
				(7.95)				(25.69)
$N=4$				-0.76				-0.85
				(5.00)				(15.18)
$N=5$				-12.73 *				-66.80 **
				(7.15)				(29.23)
$D_{\text{(Dam)}}$	-22.19 ***	-22.61 ***	-22.90 ***	-27.49 **	-28.14	-28.65	-29.12	-70.90
	(8.26)	(8.58)	(8.42)	(10.78)	(20.85)	(20.58)	(20.32)	(35.76)
$D_{\text{(Generator)}}$	3.46	2.29	1.36	2.52	46.98	45.52	44.19	44.52
	(7.91)	(7.73)	(7.49)	(6.71)	(31.18)	(32.42)	(32.18)	(29.77)
$D_{\text{(Trans. lines)}}$	18.79 **	20.20 *	21.43 **	12.14	47.30	49.02	50.91	22.61
	(9.06)	(10.30)	(10.24)	(12.38)	(49.15)	(50.03)	(49.03)	(49.22)
$D_{\text{(Substation)}}$	23.07 ***	23.49 ***	23.47 ***	22.05 ***	-46.17 **	-45.62 **	-45.63 **	-49.27 **
	(6.05)	(5.99)	(5.87)	(6.75)	(21.46)	(21.62)	(21.12)	(19.62)
$D_{\text{(Civil work)}}$	19.69 ***	20.46 ***	21.02 ***	25.01 ***	73.11 **	74.03 ***	74.78 ***	98.01 ***
	(4.23)	(4.37)	(4.44)	(5.09)	(28.54)	(28.24)	(28.19)	(34.95)
Installed capacity	-0.01	-0.01	-0.01	0.02	0.35 **	0.35 **	0.35 **	0.39 **
	(0.04)	(0.04)	(0.04)	(0.02)	(0.17)	(0.17)	(0.17)	(0.16)
Installed capacity^2 1/	-0.05	-0.05	-0.05	-0.05 **	-0.24 *	-0.24 *	-0.25 *	-0.23 *
	(0.04)	(0.03)	(0.03)	(0.02)	(0.15)	(0.14)	(0.14)	(0.13)
Number of turbines	7.83 ***	7.39 ***	8.06 ***	4.38 **	-8.13	-8.67	-7.74	-20.18 *
	(1.60)	(1.56)	(1.55)	(2.06)	(9.50)	(9.24)	(9.79)	(12.09)
Trans. line voltage	-0.27 ***	-0.23 **	-0.25 ***	-0.21 **	0.60	0.65	0.61	0.68 *
	(0.09)	(0.10)	(0.09)	(0.09)	(0.44)	(0.45)	(0.44)	(0.41)
Trans. line voltage^2 1/	0.51 ***	0.47 **	0.48 ***	0.46 **	-1.29 *	-1.35 *	-1.33 *	-1.23 *
	(0.16)	(0.18)	(0.16)	(0.18)	(0.78)	(0.79)	(0.78)	(0.72)
Trans. line length	0.06	0.00	0.03	-0.10	-0.76 *	-0.83 *	-0.78 *	-1.17 **
	(0.08)	(0.09)	(0.08)	(0.10)	(0.45)	(0.43)	(0.45)	(0.52)
Trans. line length^2 1/	-0.07	-0.05	-0.05	0.08	0.88 *	0.90 *	0.89 *	1.31 **
	(0.09)	(0.09)	(0.09)	(0.11)	(0.49)	(0.49)	(0.49)	(0.57)
Engineering cost	1.22 ***	1.22 ***	1.21 ***	1.19 ***				
	(0.10)	(0.10)	(0.10)	(0.09)				
Estimated duration	-0.40	-0.20	-0.23	-0.04	-1.13	-0.88	-0.92	-0.19
	(0.20)	(0.24)	(0.20)	(0.23)	(0.76)	(1.00)	(0.83)	(0.76)
Donor 1	43.86 **	39.10 ***	38.57 ***	33.44 ***	85.61	79.75	78.87	50.09
	(12.87)	(13.76)	(12.83)	(12.17)	(58.99)	(65.26)	(61.85)	(47.43)
Constant	16.30	26.93	27.71 *	2.14	44.77	57.83	58.68	13.74
	(13.90)	(19.17)	(15.24)	(16.53)	(39.23)	(52.50)	(42.45)	(51.41)
Obs.	139	139	139	139	139	139	139	139
R-squared	0.981	0.981	0.982	0.983	0.779	0.779	0.780	0.811
Number of dummies								
Country	12	12	12	12	12	12	12	12
Bidder nationality	15	15	15	15	15	15	15	15

1/ For presentation purposes, the coefficients are multiplied by 1,000.

Note: The dependent variable is the bidding amount. The robust standard errors are shown in parentheses. *, ** and *** indicate the 10%, 5% and 1% significance levels, respectively.

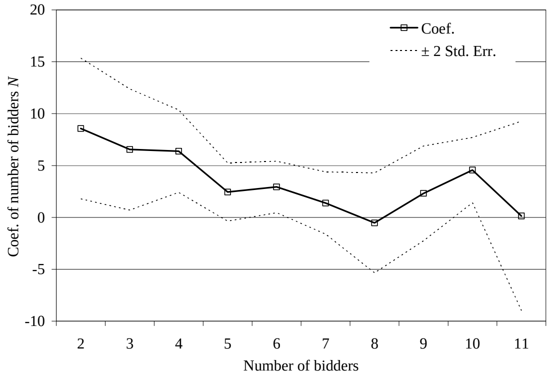
Source: Author’s calculation.

Regardless of sectors, the competition effect is broadly negative and statistically significant, as expected. The significance may differ depending on specifications. In road-related procurements, the equilibrium bid tends to decrease with the number of bidders involved, even in the most flexible model, which is partially nonparametric. As depicted in Figure 8, competition matters as N increases up to seven. Beyond that level, the competition effect tends to taper off.

In the water and sewage sector, similarly, it seems that at least seven bidders are needed for an auction to be competitive enough (Figure 9). There is an unexpected negative coefficient associated with the case of $N=2$. But it is statistically insignificant; the null hypothesis that the coefficient is not different from that of $D_{(N=3)}$ cannot be rejected at the conventional significance level. The parametric models also support the pro-competitive effect of the number of bidders (Table 5).

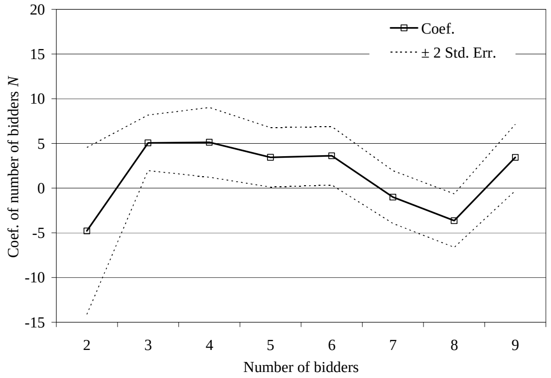
In the electricity-sector auctions, the estimated competition effect diminishes quickly, as N increases (Figure 10). If more than two firms participate in an auction, the incremental competition effect appears ambiguous. Three firms are enough according to our sample data. However, a fundamental question about the dynamic (endogenous) competition effect remains to be answered. Given the very skewed bidder participation distribution (Figure 7), it is technically infeasible to assess the potential competition effect beyond the supported range. It is far from conclusive whether the equilibrium bid would decline if a large number of firms—say more than five—participate in the procurement process for electricity projects.

Figure 8. Predicted Competition Effect for Road Contracts



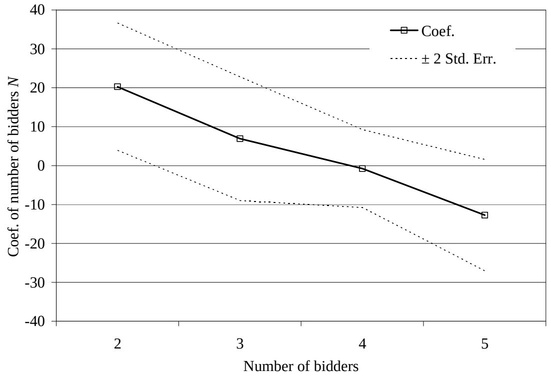
Source: Author's calculation.

Figure 9. Predicted Competition Effect for Water Projects



Source: Author's calculation.

Figure 10. Predicted Competition Effect for Electricity Projects



Source: Author's calculation.

Many coefficients of contract-specific attributes may have counterintuitive signs when the engineering cost estimate is included in the equation. The reason is that the engineering cost variable has too strong explanatory power, leaving little variation for other independent variables. The models without engineering cost estimates provide a much clear insight. Suppose that the engineering cost would be calculated based on other independent variables, i.e., $COST_t = X'_t \theta + u_t$. Then, it is found that the equilibrium bid is an increasing function of road length and width, as expected. The estimated coefficient is about 0.25, meaning that an additional 1 km of road costs 0.25 million U.S. dollars (Table 4). It is clear that larger water treatment capacity will be more costly and long water distribution pipes are also costly (Table 5). The cost of procuring electricity generators increases with the size of installed capacity (Table 6).

Based on these estimated bid functions evaluated at the mean values, the average equilibrium bid is calculated. This is the predicted cost of an artificial "average infrastructure contract."[12] It is worth recalling that there is no actual contract associated with this cost. The contract theoretically involves, for instance in the road case, 49 km of roads with 2.9 lanes, of which 35 percent are new construction work and 30 percent are rehabilitation. For the mean evaluation points, see the summary statistics (Table 3). Roads would cost 0.5 million U.S. dollar per km on average (Table 7). A water and sewage procurement package will cost about 770 U.S. dollars per m^3 of water treatment capacity. Note this package is, roughly speaking, a half-and-half mixture of water supply and sewage facilities and includes treatment plants as well as distribution and/or collection networks. If it is only for water supply infrastructure, it will cost 780 U.S. dollar per m^3, and a sewage contract will cost 760 U.S. dollars per m^3. Electricity generation installed capacity and associated facilities cost 0.44 million U.S. dollars per MW.

Table 7. Predicted Unit Bid of "Average" Contract Package (Million US$)

	Bid amount per unit	Std. Err.
Road (per km)	0.50	(0.12)
Water & sewage (per million m3)	768.49	(137.01)
Only water supply (per million m3)	780.05	(143.29)
Only sewage (per million m3)	759.38	(133.28)
Electricity (per MW)	0.44	(0.03)

Note that the bid functions are evaluated at the mean values.

Source: Author's calculation.

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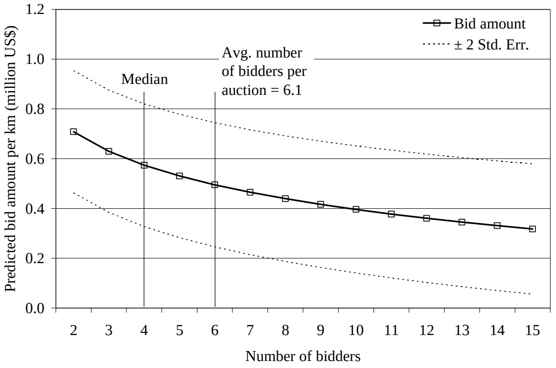
[12] It is assumed that our sample represents a typical composition of relevant sub-components in each sector.

These unit costs appear broadly consistent with the existing literature (e.g., Fay and Yepes, 2003).[13] Importantly, however, in our model the estimated unit cost varies depending on the degree of competition and contract design. As shown in Figure 11, the road unit cost is projected to be 0.7 million U.S. dollars when auction competition is minimal ($N = 2$). The figure uses the log-linear model in Table 4. It can be reduced less than 0.5 million U.S. dollars per km if more than six firms compete with one another for the contract. In the water and electricity sectors, similarly, competition will bring additional cost savings in public procurement. The projected competition effect on public procurement costs looks moderate in the water sector (Figure 12). Note that the statistic reliability is particularly low in the electricity case (Figure 13).

Figure 11. Predicted Bid Amount per Unit: Roads



Source: Author's calculation.

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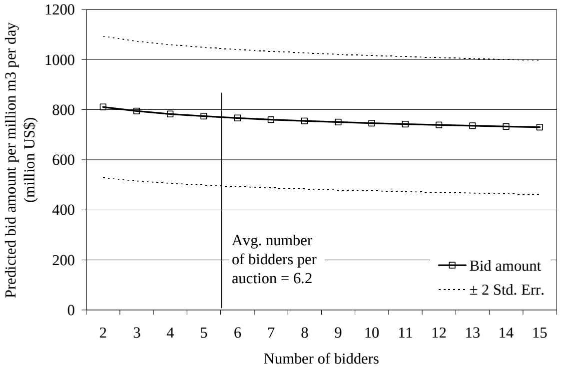
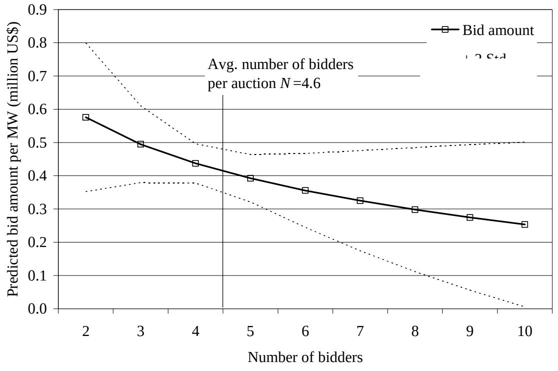
[13] Fay and Yepes (2003) assumes that the unit cost of electricity infrastructure is $1.9 million per MW; for roads, $0.41 million per km; for water connection, $400 per household; and for sanitation connection, $700 per household.

Figure 12. Predicted Bid Amount per Unit: Water



Source: Author's calculation.

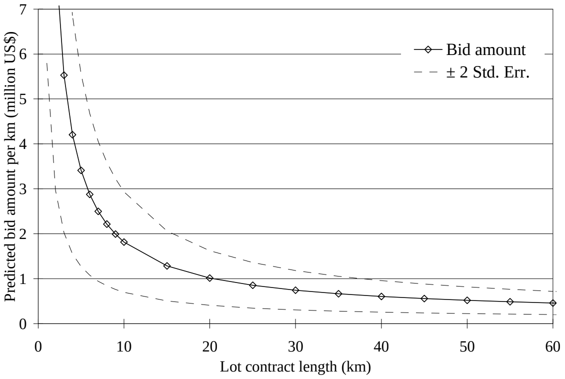
Figure 13. Predicted Bid Amount per Unit: Electricity



Source: Author's calculation.

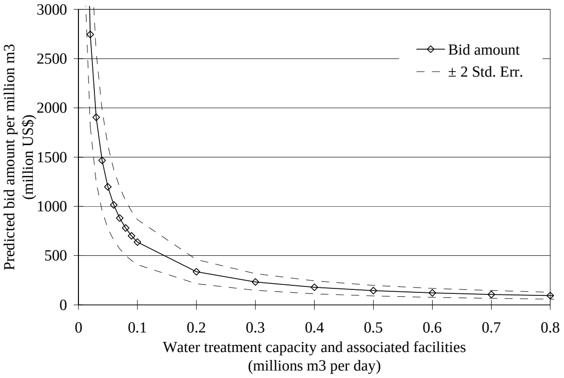
In addition, the predicted unit cost is significantly affected by contract design, especially the size of contract. When the estimated equilibrium bid function for road projects is evaluated with different lengths of roads, it is evident that a road of less than 10 km would be extremely expensive (Figure 14). Hence, how to design lot packages is an important issue. As expected, large electricity projects have a lower unit cost, because of economies of scale. This fact calls for close collaboration among subnational governments—or communities, or neighboring countries, depending on the individual context—at the project preparation stage. Similarly, small projects with less than 100,000 m^3 of water treatment capacity or less than 100 MW of electricity installed capacity will be expensive disproportionally (Figures 15 and 16). However, large contracts will create another problem that only a small number of firms can apply for such auctions. There is a tradeoff between competition intensity at auctions and economies of scale in procurement.

Figure 14. Predicted Road Unit Bid by Lot Length



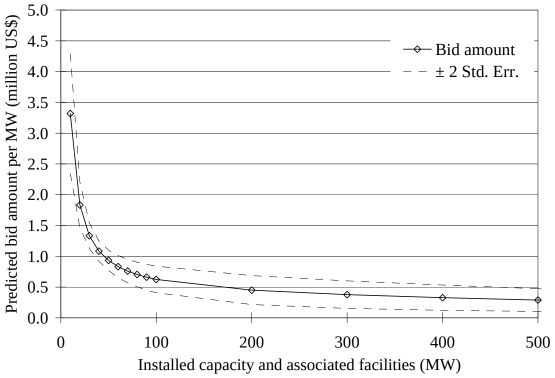
Source: Author's calculation.

Figure 15. Predicted Water and Sewage Unit Bid by Treatment Capacity



Source: Author's calculation.

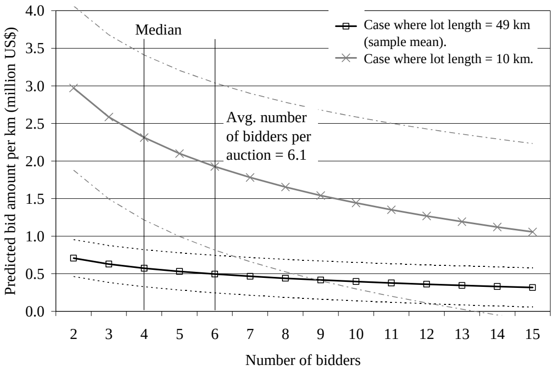
Figure 16. Predicted Electricity Unit Bid by Installed Capacity



Source: Author's calculation.

The competition effect is of greater importance when the size of contract is particularly small. This is intuitively clear; as shown above, the unit cost tends to decrease with the size of contract, meaning that the contract amount for a small project will be relatively high and may be profitable for contractors. At the same time, for a relatively small contract, a number of firms are expected to apply. Therefore, it is reasonable that the competition effect would play a powerful role in curtailing procurement costs of small projects. Figure 17 illustrates two competition effects evaluated at different contract sizes.

Figure 17. Predicted Road Unit Bid by Size and Competition



Source: Author’s calculation.

The estimated bid functions allow to calculate the average unit cost of each project element contained in a standard contract. Except the road case, the above “average package” concept may not be clear enough. By setting irrelevant attributes at zeros, for instance, the cost of installing a 100 MW generator can be estimated at about one million U.S. dollars per MW (Table 8). Obviously, the unit cost is much lower due to economies of scale if a larger turbine is purchased. An installation work of 10 km transmission lines will cost 89 million U.S. dollars. Again, if only 1 km of transmission line is put in place, it will be prohibitively expensive. The unit cost would likely decline dramatically when the bulk of transmission lines are contracted out all together.

Table 8. Predicted Unit Bid of Individual Item: Electricity
(Million US$)

Generator installation	Bid amount per unit	Std. Err.
10 MW	7.78	(2.55)
100 MW	1.07	(0.35)
500 MW	0.38	(0.14)
1,000 MW	0.18	(0.06)
Transmission line installation		
1 km	96.14	(45.38)
10 km	8.92	(4.24)
25 km	3.11	(1.52)
50 km	1.20	(0.65)
100 km	0.27	(0.30)

Source: Author's calculation.

From the water-sector bid function, similarly, it is found that a water treatment plant with a daily production capacity of 0.5 million m^3—which may be usable in a medium-sized city with 1–2 million of population—would cost about 58 U.S. dollars per m^3 per day (Table 9). If a water treatment plant produces only 0.1 million m^3 of water per day—as in a smaller town—it will cost more than 200 U.S. dollars per m^3.[14] The unit cost is 3 times as high as the procurement package of 0.5 million m^3 of treatment capacity.

Table 9. Predicted Unit Bid of Individual Item: Water and Sewage

Water treatment plant	Bid amount per unit	Std. Err.
0.01 million m3 per day	777.85	(323.11)
0.05 million m3 per day	329.94	(49.45)
0.1 million m3 per day	202.52	(26.14)
0.5 million m3 per day	57.94	(7.62)
1 million m3 per day	32.73	(4.52)
Waste water treatment plant		
0.01 million m3 per day	609.72	(309.97)
0.05 million m3 per day	296.32	(28.78)
0.1 million m3 per day	185.71	(11.87)
0.5 million m3 per day	54.58	(4.84)
1 million m3 per day	31.04	(3.22)
Iron pipe installation		
1 km	9.22	(1.27)
5 km	2.14	(0.22)
10 km	1.13	(0.11)
50 km	0.26	(0.02)
100 km	0.13	(0.01)
500 km	0.03	(0.00)

Source: Author's calculation.

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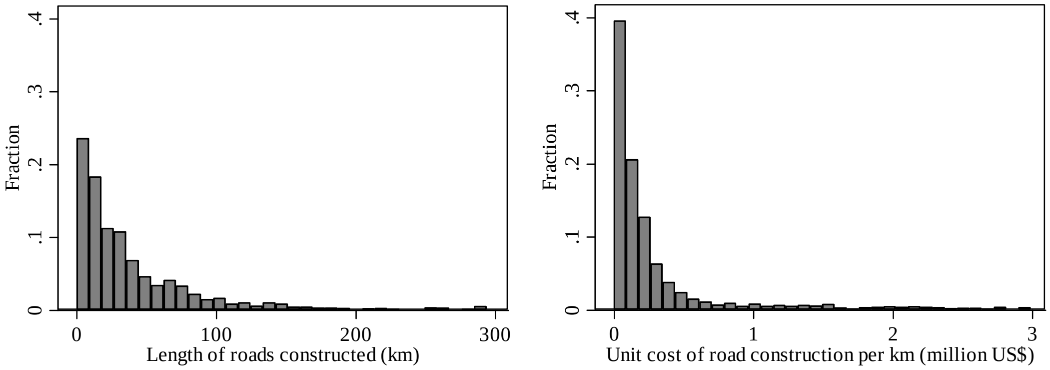
[14] These estimated costs are broadly consistent with the actual development costs of water treatment plant construction projects, which may range from 60 to 300 U.S. dollars per m^3 per day.

V. DISCUSSION

Financial needs for infrastructure development: revisited

As mentioned above, an important problem in the previous literature forecasting the infrastructure financial needs is that the unit cost is assumed constant, whatever its basis is. It means that the roles of procurement efficiency and contract design are ignored.[15] However, these cannot be underestimated as shown in the previous section. In reality, for instance, how to design road procurements is crucial to contain government purchasing costs (Grimm, *et al*., 2006). The ROCKS database covering more than 3,000 road contracts over the developing world reveals that the majority of road contracts are less than 60 km, which would result in higher unit costs than our efficient procurement price, holding other conditions constant; these contracts were in fact awarded with extremely high unit prices (Figure 18).

Figure 18. Size and Unit Cost of Road Contracts



Source: Author's calculation based on ROCKS database.

Using our estimation results, the financial needs are reassessed with particular focus on procurement efficiency and less attention paid to the quantity side. We concentrate on examining the unit price impact. The quantity of infrastructure demand—thus supply—is projected by the simple cross-country bivariate relationship between economic development

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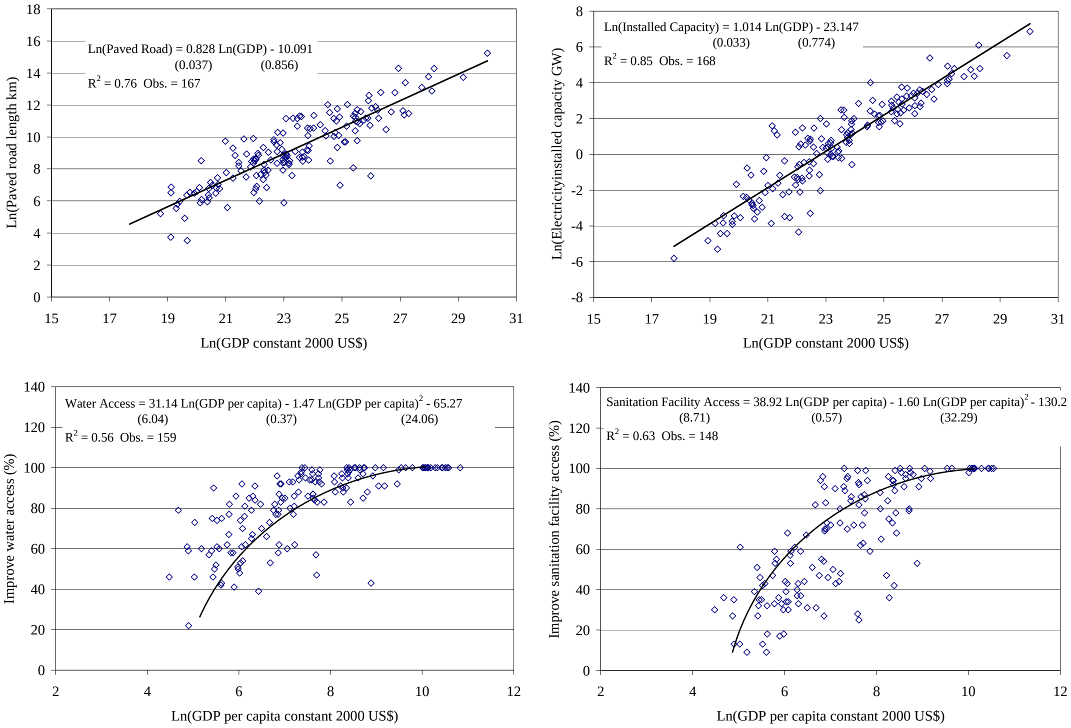
[15] Fay and Yepes (2003) assumes that the unit cost of electricity infrastructure is $1.9 million per MW; for roads, $0.41 million per km; for water connection, $400 per household; and for sanitation connection, $700 per household.

and infrastructure accumulation (Figure 19).[16] A constant elasticity of paved road stocks with respect to GDP is estimated at 0.828. Using the average real growth rate in the past five-year, the annual growth rate in paved roads in each country is calculated. The elasticity of electricity capacity is almost unity. The elasticity of improved water and sanitation access with respect to per capita GDP varies depending on development level. Notably, additional populations with water supply and sewage access are calculated separately, though our bid function cover both simultaneously. But they are basically independent systems. This calculation *does* ignore the causality problem for simplicity. But in our argument it does not matter which causes which. The important fact is that more infrastructure capacity is required to support economic growth and such positive correlation is very predictable even in a simple regression.

Figure 19. Correlation between Economic Development and Infrastructure Stocks



Source: Author's calculation from *World Development Indicators* and Energy Information Administration.

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[16] This follows, for instance, World Bank (1994). For more sophisticated empirics, see Canning and Pedroni (1999), Fay and Yepes (2003), and Calderón and Servén (2004). While Calderón and Servén estimate the impact of infrastructure quantity and quality on economic growth, Fay and Yepes estimate the effect of economic growth and other conditions on infrastructure accumulation.

The total impact of improving auction efficiency is found enormous on the aggregate level. Table 10 reveals that competition could save a lot of public resources and aid money. It amounts to roughly 32 billion U.S. dollars a year, which is equivalent to 8.2 percent of total infrastructure (electricity, roads, water and sewage) development costs. While the baseline refers to the average level of competition in the sample, the efficiency scenario assumes that competition is increased to the optimal level.[17] On the quantity side, the incremental infrastructure requirements are calculated by applying the average economic (GDP or per capita GDP) growth rate for the past 5 years to the above relationship in Figure 19. For all sectors combined, the annual financial needs are estimated at about 392 billion U.S. dollars under the baseline assumption and about 360 billion U.S. dollars in the efficiency scenario.

Table 10. Predicted Financial Needs for Infrastructure Development
(Million US$)

	Memorandum: Fay and Yepes' estimates (2003)			Roads		Electricity (118 MW case)		(30 MW case)		Water & Sewage (80,000 m3 case)		(50,000 m3 case)	
	Roads	Electri-city	Water & Sewage	Baseline	Efficient auction	Baseline	Efficient auction	Baseline	Efficient auction	Baseline	Efficient auction	Baseline	Efficient auction
East Asia & Pacific	20,608	43,378	9,871	75,012	70,482	22,227	19,954	72,646	63,647	10,483	10,373	16,332	16,153
Europe & Central Asia	26,254	32,976	5,037	46,313	43,516	13,878	12,458	45,356	39,738	1,981	1,960	3,086	3,052
Latin America & Caribbean	6,919	25,627	5,026	4,940	4,642	4,139	3,716	13,528	11,852	469	464	731	723
Middle East & North Africa	6,924	11,932	2,749	8,082	7,594	2,124	1,906	6,941	6,081	546	541	851	842
South Asia	22,328	18,110	7,792	57,677	54,194	5,456	4,898	17,832	15,624	6,581	6,512	10,254	10,141
Sub-Saharan Africa	7,523	6,214	4,513	5,248	4,931	1,396	1,254	4,564	3,998	2,092	2,070	3,260	3,224
Total (sector)	90,556	138,237	34,988	197,272	185,359	49,220	44,186	160,866	140,941	22,153	21,920	34,514	34,133
Efficiency gains					11,913		5,034		19,926		234		380
% of total cost					6.0		10.2		12.4		1.1		1.1
Grand total			263,781									392,652	360,433
Efficiency gains													32,219
% of total cost													8.2

Source: Author's calculation.

Our finding is supportive of the positive nexus between growth and good governance. In the existing literature, especially growth empirics, the growth-governance linkage has been ambiguous (Burnside and Dollar, 2000; 2004; Easterly, *et al.*, 2004). The main reason is that one could not agree on the definition of "good governance" (e.g., Easterly 2003). It may include a wide range of factors from political stability to government effectiveness. But as far as public procurement is concerned, good governance can be measured as efficiency in

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[17] From the above discussion, seven firms are required for road and water procurements. While the baseline case assumes *N=4*, the optimal level in the electricity projects is assumed five. This is because the sample mean of the number of bidders is already 5.3.

auctions, and the magnitude of likely efficiency gains has been estimated at some 8 percent of total costs. This is considerable compared with the corruption cost, which is, for instance, about 3½ percent of public contract amounts in Sub-Saharan Africa. It is also unignorable from the fiscal point of view; the savings of 32 billion U.S. dollars are approximately 0.4 percent of GDP of the developing world.

Compared with Fay and Yepes (2003), there are several discrepancies. But this is mainly because of the difference in quantity forecasts. The predicted increases in infrastructures for China, India and several Eastern European countries may be overestimated in our estimates, reflecting their recent strong economic buoyancy. It is true that accelerated growth would require more rapid accumulation in infrastructure, but the supply capacity is a typical problem that developing countries are faced with. Because these countries are much large, the financial need estimates can be easily inflated. In other regions (Latin America and the Caribbean, Middle East and North Africa, and Sub-Saharan Africa), the estimated requirements are quite comparable with the existing estimates.

Another important remark is that “the scale of projects needs to be tailored to economics and technology (World Bank, 2006).” In many cases, the unbundling and medullar approach are appropriate to deliver infrastructure services. However, it turns out a mistake to pursue for the segmented structure if the markets are small, as evident in the World Bank’s early experience in the electricity sector. As shown, the unit cost of electricity projects differs considerably depending on project and procurement design. According to our estimation results (Figure 15), 1.9 million U.S. dollars per MW assumed in the previous study seems a relatively high unit cost, which is expected to be realized when a small installed unit is procured. When evaluating the estimated bid function at a capacity of 30 MW, the financial requirements turn out consistent with the existing forecasts. Obviously, there are technical constraints to install large-size generators. On one hand, smaller generators may be needed for remote areas, and on the other hand, regional collaboration is one possibility to increase scale economies (i.e., achieving the minimum efficient size). In particular in Africa, many opportunities remain for collective development and operation of infrastructure. For instance, Africa has more than 60 shared rivers, which can be interpreted as opportunities for regional cooperation in water development and management (World Bank, 2005).

Donors also have to coordinate with each other. In the health sector, which has become a major recipient of aid, an emerging concern is that an ever-increasing proportion of assistance for health from a large number of donors through vertical funds could lead to increased transaction costs for governments (OECD, 2008). If donors concentrate on small-scale infrastructure assistance without coordination, the same problem would occur.

Notably, there are many simplifications in the above calculation. First, our prediction of infrastructure demand and supply in terms of quantity is very static but not dynamic in a statistical sense. It may or may not be correct. But the measured efficiency gains on the unit cost side are reliable. Second, our unit costs are associated with a basket composed of various sub-components necessary for an "average" development project in our sample (Table 7). It covers not only main components, such as generators and treatment plants, but also their associated facilities. We implicitly assume that the composition of these sub-elements in our sample represents the whole picture of infrastructure projects. But this may not be true. Related to this, third, our efficient unit costs still have reservations, because project specifications are different in reality. Not all roads are supposed to be paved and have two lanes—more precisely 2.9 lanes in our case. Not all people are required to be supplied treated and piped water. Some may rely on clean well-water. Finally, in the case of the water and sewage sector, the projected demand for improved water access is converted to the volume of water produced by assuming that per capita per day water consumption is 413 liters.[18] This is merely a simple conversion factor.

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[18] Although there is considerable difference in per capita water consumption among countries, the average water consumption (both residential and industrial) per capita per year is estimated at 151 m^3, which is 413 liter on a per day basis (World Water Organization).

Africa-specific effects?

Another interesting policy question is whether the conventional Africa-specific negative effect is observed. A number of cross-country studies, throwing a dummy variable for Africa in the model, have demonstrated that African countries share some unobserved characteristics, which usually have adverse effects on economic development.

Sachs and Warner (1997) attributes Africa's slow growth to poor governance, landlockness and the dynamic Dutch disease syndrome associated with abundant natural resources. It is true that many African countries do not have physical and effective access to the sea. Iimi (2007) also indicates the extent that natural resources are properly linked to growth is dependent on governance; many African countries are lagging behind in this area. Glaeser *et al*. (2004) shows that human capital is more important for growth than the institutions. On the other hand, it may be just because of geographic conditions, such as temperature and precipitation, along with structural poverty traps (Bloom, *et al*., 2003).

In our results, there is no clear indication that African countries bear high procurement costs because of "unobserved African factors." The estimated country-specific fixed effects are different from sector to sector. In our *limited* sample countries, Africa's road procurement costs are not systematically increased by unobservables. The normalized country dummy coefficients for Ethiopia and Ghana are relatively low compared with other regions (Figure 20).[19] But the Swaziland-specific effect may be among the highest.

In the water and sewage sector, Tanzania's project costs may be systematically high. However, this cannot be over-generalized because of our narrow country coverage. In the electricity sector, it is found that most African countries in our sample, such as Nigeria, Tanzania and Uganda, bear additional infrastructure project costs associated with some unspecified elements in our models. This is consistent with the conventional "Africa-specific" adverse effect view. Further analysis is required to examine what it is.

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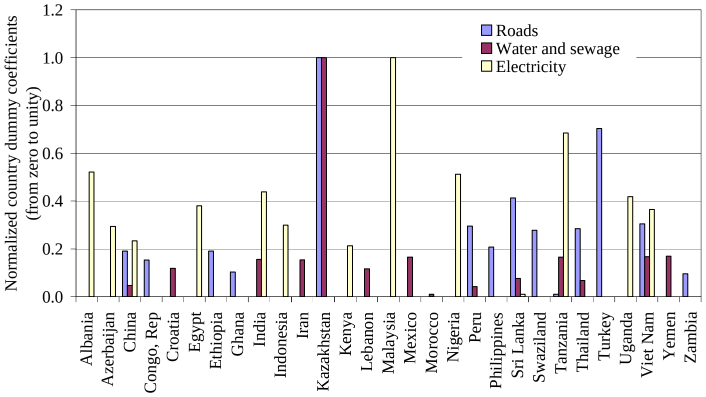
[19] This does *not* mean that Africa's project costs are relatively low. Rather, it means that there is no evidence that African countries would have a common unobserved factor affecting the public procurement results.

Figure 20. Normalized Country-Specific Effects on Equilibrium Bids



Note: The baseline (smallest coefficient) is Tanzania for roads, Morocco for water and sewage, and Sri Lanka for electricity. Countries without bars do not have relevant projects in our sample.

Source: Author’s calculation.

In sum, some of the direct policy implications from all the discussion are as follows:

- Competition is important to increase auction efficiency in procurement auctions for road and water infrastructure projects and to a lesser extent in the electricity sector.
- Auctioneers are encouraged to increase bidder participation, preferably to involve seven or more firms per auction.
- Even on our efficient procurement cost basis, the financial needs of developing countries for infrastructure development are sizable at about 360 billion U.S. dollars per annum. Greater efforts are required toward improving efficiency in public investments.
- The total benefits from improved auction efficiency will reach 8.2 percent of total investment costs.
- Auction design does also matter for infrastructure cost minimization. Small procurement contracts are prohibitively expensive. In preparing infrastructure projects, coordination among subnational governments, communities, or neighboring countries is useful to containing procurement costs.

VI. CONCLUSION

Infrastructure is recognized as the engine for economic growth. Public resources are not sufficient for infrastructure development in developing countries. It is still arguable whether the public resources are used efficiently, particularly where the public procurement systems are fragile.

The paper, using auction data on official development assistance for infrastructure projects, focuses on efficiency in public procurement. In theory, competition is a key to increasing auction efficiency and thus achieving the lowest possible procurement costs. Intensified competition is also instrumental in preventing collusion and corruption and promoting local business development.

A main question is how much competition could contribute to reducing infrastructure investment costs. This is an attempt to quantify the impact of a particular form of public governance improvement on the economy. The paper examines how many bidders are required toward procurement efficiency. Three infrastructure sectors are analyzed: roads, water and sewage, and electricity.

The current level of in the infrastructure procurement process is not so high, except for road procurements. The estimated equilibrium bid functions generally support the view that by encouraging more competition a lot of public resources and aid money could be saved. It is shown that in road and water projects, at least seven firms are required for an auction to be competitive enough. The required level of competition for electricity projects may be much lower, perhaps at three, but this is less conclusive.

Unlike the existing literature, the current paper highlights the importance of procurement efficiency to contain infrastructure procurement prices, which have rarely been questioned in the past. By increasing competition to the optimal levels, the predicted financial needs could be reduced considerably. Under several simple assumptions, total benefits are estimated at 8.2 percent of annual infrastructure investment costs.

It is also found that how to design lot contracts, especially the size of contracts, is another important factor to achieve the lowest possible procurement costs. It will be costly to divide a project into a number of small-scale lot contracts, though more competition can be expected. Procuring an infrastructure project under a single contract would generally help bring cost savings. But it may limit firms who can apply for such a large contract. It is important to balance the tradeoff between competition in auctions and economies of scale in procurement.

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