INFRASTRUCTURE PROCUREMENT AND EX POST COST ADJUSTMENTS
EVIDENCE FROM ODA-FINANCED ROAD PROCUREMENT IN AFRICA

December 2009
(Revised)

Atsushi Iimi[¶]
World Bank (FEU)

Abstract

The paper readdresses the post-award adjustment problem in infrastructure procurement. Cost overruns and project delays have long been chronic difficulties in implementing infrastructure projects. Too many ex post adjustments not only incur significant adaptation costs to contractors but also undermine efficiency, credibility and predictability of the budget execution. The paper analyzes the case of public road procurement in Sub-Saharan Africa. It is found that if large post-award amendments are anticipated, bidders are likely to reflect them to their bids systematically. Under the perfect foresight assumption, one dollar of anticipated contract adjustment would decrease the bid strategy by 7 cents; the effect seems to be offset largely by the incurred adaptation cost to contractors, which is estimated at 93 cents per one dollar of contract adjustment. Therefore, the ex post adaptation approach is much costly, and it may be better to formulate the accurate budget on a more solid basis and use the agreed contract as high-powered incentives to contractors.

Key words: Public procurement; auction theory; ex post adjustment; infrastructure development; governance.

JEL classification: C21, D44, H54, H57.

[¶] I am most grateful to Antonio Estache and Cesar Queiroz for their insightful comments on an earlier version of this paper.

I. INTRODUCTION

Public infrastructure procurement is still a challenging task for governments because the objects being procured are usually expensive and complex. Even with a small flaw of procurement design, a significant amount of public resources could be lost. In addition, infrastructure works are technically complicated and full of uncertainty. If governments knew who is the most efficient contractor, they could directly negotiate with that company and achieve efficiency. However, governments normally do not know the lowest-cost firm in the market (i.e., asymmetric information). Auction theory may contribute to guiding procurement authorities on how to search the best contractor. But a crucial shortcoming of traditional auction theory is that the contract is assumed complete and binding in legal terms. However, because of the complexity and uncertainty, public work contracts are often left incomplete, thereby requiring post-award adjustments. Ex post amendments not only incur some adaptation costs on contractors but also create a crucial incentive problem in auction and contract theory.

The main objective of the current paper is to estimate the cost of adapting post-award adjustments, namely cost overruns and project delays, by examining the bidding behavior in infrastructure procurement in Africa. Public road procurement is analyzed in this paper. From the contract theory point of view, Bajari and Tadelis (2001) highlights a clear tradeoff between providing right incentives and reducing ex post renegotiation costs. Rigid fixed-price contracts can strongly incentivize contractors to contain costs but will require more contract design costs to reduce inefficient ex post renegotiation. Moreover, if the contract turns out incomplete, the adjustment cost would be significant. By contrast, under the more flexible regime, such as cost-plus contracts, adjustments may be less costly because renegotiation friction is eliminated. Apparently, however, there is no incentive for cost reduction.

In large-scale public infrastructure procurement, an increasing number of pieces of evidence show that post-award adjustments have taken place for various reasons, such as defective

specifications and unpredictable site conditions at the time of project design (e.g., Guasch, 2004; Flyvbjerg, 2005; Bajari *et al.*, 2006; Blanc-Brude *et al*., 2006). Official development assistance (ODA) projects are no exception to this. Many ODA-financed projects have long incurred massive cost overruns and delays in completion (Alexeeva *et al*., 2008). A particular problem in ODA-financed projects is that potential ex post contractual changes may not follow a solid rule but be considered as ad hoc opportunities.

Important, the chronic cost overruns and project delays would add additional difficulties for governments to implement infrastructure projects. First, incompleteness of public work contracts impinges upon the selection mechanism of contractors, because contractors would have an incentive to submit unrealistic bids on public tenders, often referred to as "low balling," if they believe that renegotiation is allowed after the contract is awarded (Ware *et al*., 2007). Contracting with incompetent and faithless contractors will lead to a massive waste of public resources (e.g., Olken, 2005; Gulati and Rao, 2007). Second, because of the biased project cost estimates and schedule, the government's project prioritization policy will become inefficient and make public financial management unpredictable and noncredible. This will have a negative effect on growth over the long term. Therefore, how much ex post adjustments would cost is an important question, and if they turn out costly, it would be essential to detect unrealistic low-balling bids and contain project cost overruns and delays in a more solid way.

The current paper uses the case of public road procurement in Africa where public resources tend to be limited, misprocurement and misuse are alleged concerns, governance in public procurement systems is generally poor, and cost overruns and project delays are considered to have a particularly large adverse effect on economic growth. Technically, the paper aims to infer the implicit cost of ex post adjustments by estimating the equilibrium bid function under the framework involving both common and private values. It employs a conventional instrumental variable (IV) technique and the two-stage quantile regression (2SQR) model. It will be shown that ex post adjustments would be much costly; the implicit cost may reach 93 cents per one dollar of contract adjustment.

The remaining paper is organized as follows: Section II provides a literature review relevant to the issues of competitive bidding and ex post adjustments. Section III overviews the infrastructure procurement market financed official development assistance (ODA) and our used data in the road sector. Section IV reviews a theoretical framework, based on which Section V develops our empirical model. Section VI presents our main empirical results and discusses several policy implications. Then, Section VII concludes.

II. BRIEF LITERATURE REVIEW

In traditional contract theory, when a principal, namely government, cannot observe some critical information of its agent, such as agent's made efforts and its type, fixed payment arrangements would be better than cost-plus contracts to the extent that the former entitle the agent to retain a potential savings and therefore maximize its effort toward cost cutting (e.g., Laffont and Tirole, 1993). Under the incomplete contract setting, it is generally shown that ownership matters in favor of higher-powered incentives, which can be interpreted as the fixed payment regime or private ownership (Grossman and Hart, 1986; Hart *et al.*, 1997; Besley and Ghatak, 2001; Hart, 2003).

With a bargaining game for ex post revision taken into account, Bajari and Tadelis (2001) shows a trade-off between resolving ex post incentive problems and minimizing costs at the ex ante phase of contracting. In their model, a crucial parameter is the cost of ex post adjustments or the complexity of a project being procured. When an object being procured is highly complex, customized and costly to design and specify the details, as in many infrastructure projects, cost-plus contracts, i.e., ex post adjustable arrangements, may be preferred to hard incentive contracts. However, one major disadvantage is the lack of incentive to contain project costs.

Similarly, from the auction theory point of view, it is shown that the selected contract will provide the winning firm with the possibility for positive profits either built into the payment function (ex ante) or as a result of cheating (ex post) (Fishe and McAfee, 1987). McAfee and McMillan (1986) also models competitive bidding for a public contract under the assumption that some aspects are not contractible. When payment is designed as a linear combination of each bidder's bid price (fixed-payment) and a stochastic term (cost-plus payment), neither the pure fixed-payment nor the pure cost-plus contract would be considered optimal. Rather, the best contractual mechanism should reflect both fixed payment and cost-plus arrangements.

In infrastructure procurement, public work contracts do not seem to be complete or firmly binding in reality. Because large-scale infrastructure projects are highly complex and take more than several years to complete, certain adjustments after the contract award may be unavoidable or necessary to a greater or lesser extent. However, evidence shows that public infrastructure procurement has too often undergone ex post renegotiation. As per Flyvbjerg *et al*. (2002), almost 9 out of 10 projects experienced some cost overruns in transport (rail and road) infrastructure projects in 20 developed and developing countries over the world. The average cost escalation during project implementation is estimated at 27.6 percent. In addition, project delays also add greatly to the cost. The cost escalation of infrastructure projects caused by the delayed construction is estimated at 4.6 percent per year (Flyvbjerg, 2005). In some African countries, the value of a public road contract exceeds its engineering cost estimate by more than 20 percent. In addition, another 20 percent would be added during the implementation period. Further, the average delay in project completion reaches 10 months (Alexeeva *et al*., 2008).

The recent literature highlights the problem of prevailing post-award adjustments in infrastructure procurement in the public-private partnership (PPP) context (e.g., Guasch, 2004; Guasch *et al*., 2007; 2008). Compared with traditional infrastructure procurement, PPP auctions are a classic example involving relatively large common uncertainties, e.g., political and regulatory risks. Renegotiation or cost overruns can be considered as a typical symptom

of the winner's curse, and Guasch (2004) shows that about 30 percent of PPP infrastructure transactions underwent renegotiation within two years after the awards in the Latin American and Caribbean region. In the United Kingdom 55 percent of public finance initiative (PFI) projects experienced some changes in the public works contracts (NAO, 2001).

Regardless whether traditional or PPP, too frequent ex post adjustments will cause substantial implicit as well as explicit costs on contractors, governments, and citizens or taxpayers. Besides the risk of cost overruns for unexpected but purely explainable, physical reasons, the incurred implicit cost of adapting ex post adjustments may be considerable. Bajari *et al.* (2006) estimates the adaptation cost reflected in the real bids on the U.S. highway contracts at about 2.7 dollars per one dollar of expected contract adjustment. Blanc-Brude *et al*. (2006), examining the road construction cost, find that PPP road construction is 24 percent expensive than traditional public road procurement in Europe, possibly because the cost of PPP might have already reflected a risk premium of cost overruns.[1] In other words, this premium can be interpreted as a true additional cost of cost overruns that governments and bidding firms must have ignored in traditional road procurement auctions.

The risk that governments would pay more for the adaptation cost can be particularly significant in public infrastructure projects, because by no means can the government's ultimate responsibility of providing public infrastructure services governments be transferred to private contractors. Once projects are launched, governments would have little bargaining power against contractors (i.e., hold-up problem). Worse, the current standard public procurement systems are still not perfect to exclude incompetent and faithless contractors from the selection process and reject unrealistically low bids (Ware *et al*., 2007). The prevalent belief among contractors that public contracts are not binding is therefore problematic, augmenting the risk of contracting with opportunistic contractors and allowing them more adaptation costs.

[1] As mentioned by Blanc-Brude *et al*. (2006), this is one of the plausible interpretations of their empirical results. Other possibilities are insufficient competition in PPP transactions, corruption, and lack of the bundling effect between investment and maintenance.

To avoid contracting with faithless and irresponsive contractors, several mechanisms exist even in the current standard infrastructure procurement framework. Examples are prequalification and technical evaluation in the two-stage bidding procedure. These measures aim to pre-examine bidders' financial and technical responsiveness based on their financial, managerial and experiential backgrounds.[2] In theory, the two-stage bid evaluation systems are implementable (Che, 1993; Cripps and Ireland, 1994).[3] In practice, however, every aspect other than price taken into account may make the auction mechanism more complex and less effective. For example, prequalification will limit bidder participation, aggravating the problem that lies in the lack of competition (Estache and Iimi, 2009b). A crucial disadvantage of adopting multidimensional award criteria is that the selection process tends to be less transparent and more vulnerable to corruption; auctioneers can easily exploit their excessive discretion (Klein, 1998; Ware *et al*., 2007; Estache *et al*., 2009). Hence, cost overruns are still difficult to avoid and will likely continue to happen to this market.

In the context of developing countries, especially in Africa, these incentive problems are even more critical because of their faced severe resource constraints, underdeveloped private business capacity, and poor governance. In developing countries there is a natural tendency to prefer to contract with low-cost contractors rather than to bear additional costs for high-quality project implementation (e.g., Anthon *et al*., 2007). Discovering the lowest possible price in the market is, in fact, the primary objective of competitive bidding. However, competition in infrastructure procurement is often limited in many developing countries (Foster, 2005; Iimi, 2006; Estache and Iimi, 2009a).

[2] There are some benefits from multidimensional auctions. For instance, prequalification can contribute to fostering a solid competitive marketplace, because well-qualified firms can price their bids with the knowledge that they are competing against only adequately qualified bidders with minimum competence (ADB, 2006).

[3] In theory, sequencing the price competition and the quality qualification makes no difference. The expected outcomes are the same regardless of whether quality or price is first examined, or even simultaneously (Cripps and Ireland, 1994).

There are also alleged concerns about misprocurement, misuse, corruption and collusion (Olken, 2005; Gulati and Rao, 2007; World Bank, 2008). Olken (2005) shows that the materials procured for road construction were not used in compliance with the public contracts in Indonesia; the losses amounted to 20–30 percent of total project costs. In Madagascar, the government terminated three road contracts in 2004, which amounted to US$61.6 million in total, because of the unacceptably low quality of contractor's works since 2002. Although the contacts were awarded to the second lowest bidder, the projects were delayed and the cost was inflated by 36.5 percent compared with the original contract amount, reflecting increased prices of inputs, such as fuel and cement (Alexeeva *et al*., 2008).

Cost overruns or ex ante cost underestimation are generally significant in Africa (Alexeeva *et al*., 2008). In the road sector, for instance, the actual payments would increase by 20 percent during implementation in Ghana (Table 1). The projects are also delayed considerably, with a wide range from nearly zero in Kenya to one and a half years in Nigeria. A common problem in Africa may be that the past procurement performance does not seem to have systematically been reviewed and taken into account for the next budget formulation. In Ghana, for instance, the contract amount of a road project is lower than its engineering cost estimate, but cost overruns are still taking place systematically after the contract conclusion. The effective linkage may be missing between the ministry of finance and procurement authorities. Inefficient procurement would distort the government's original project prioritization policies and make public financial management unpredictable and noncredible.

Table 1. Average cost overruns in World Bank financed road projects
(In percent)

	$\frac{\text{Bid}}{\text{Cost estimate}} - 1$		$\frac{\text{Original contract}}{\text{Cost estimate}} - 1$		$\frac{\text{Actual payment}}{\text{Original contract}} - 1$	
	Obs.	Mean	Obs.	Mean	Obs.	Mean
All	344	46.1	73	16.6	100	7.4
Congo, Democratic Rep.	7	62.2	1	15.0	8	3.0
Congo, Rep.	22	26.9	7	21.4	6	12.9
Ethiopia	36	46.8	9	21.8	11	0.1
Ghana	37	0.9	7	–9.2	9	20.4
Kenya	15	19.7	4	2.2	4	3.1
Madagascar	21	28.7	5	7.8	6	–3.5
Malawi	11	26.3	4	11.6	7	0.5
Mauritania	7	–1.6	2	3.1	3	–5.3
Mozambique	56	108.2	9	46.5	10	16.5
Nigeria	58	60.1	9	21.7	13	22.5
Tanzania	43	27.8	7	9.7	9	–0.4
Uganda	19	53.6	6	24.8	7	1.0
Zambia	12	14.0	3	–5.1	7	1.9

III. An Overview of ODA-Financed Road Procurement Auctions in Africa

The public infrastructure procurement market is huge in many countries. In particular in developing countries, it is estimated at several to 10 percent of GDP. Public roads often account for a majority of the public investments. Aid donors have also been assisting infrastructure development intensively by disbursing about 3 to 5 billion U.S. dollars every year. However, public resources available to the developing world are still not sufficient. IMF (2005) and others (e.g., Heller, 2005; World Bank, 2005) have long called for more revenue mobilization, expenditure reprioritization and efficiency gains in public spending to enlarge fiscal space.

"[O]pen competition is the basis for efficient public procurement (The World Bank's *Guidelines: Procurement under IBRD Loans and IDA Credits*, pp. 7)." ODA-financed infrastructure procurement usually follows international competitive bidding (ICB) in the first-price sealed-bid format. Transparent, fair and nondiscriminatory competitive bidding is expected to not only promote allocative efficiency but also prevent collusion and corruption. In reality, however, competition for large-scale infrastructure contracts is often limited. In the U.S. highway construction auctions in Florida, the average number of bidders is about five,

though with a wide range from 2 to 19 per auction (Gupta, 2002). In the case of Oklahoma road construction, the average number of bidding firms is only 3.3 (De Silva *et al.*, 2003). In large-scale ODA-financed projects, about six bidders appear to have participated in a competitive bidding (Iimi, 2006; Estache and Iimi, 2008).

Despite the low level of competition observed, importantly, the competition effect is still found significant in many applications (e.g., Kessel, 1971; Brannman *et al.*, 1987; Gupta, 2002; Iimi, 2006). Under the standard setting, in theory, it is predicted that no bidder reveals its true cost parameter. This creates an asymmetric information problem to governments. As the number of bidders increases, bidders would be induced to reveal their true costs because the probability that each bidder wins the contract declines (e.g., Milgrom and Weber, 1982; Wolfstetter, 1998).

In our sample, the average number of bidders is five with a standard deviation of 2.46. But the distribution is much skewed and concentrates on 3 and 4 bidders (Figure 1). Our sample comes from the data developed by Alexeeva *et al*. (2008). From the original data, the current analysis uses only 270 winning and losing bids on 54 road procurement auctions financed by the World Bank in 12 Sub-Saharan African countries (Table 2).[4] In some cases, governments may be able to expect as many as 10 participants per auction. However, that is exceptional. In most cases, the number of bidders would be less than five.

[4] The original data contain about 450 winning and losing bids in 109 procurement auctions in 13 African countries. Only 299 bids are selected, because our empirical model requires some information of rivals' cost structure (see the following sections).

Figure 1. Probability distribution function of the number of bidders

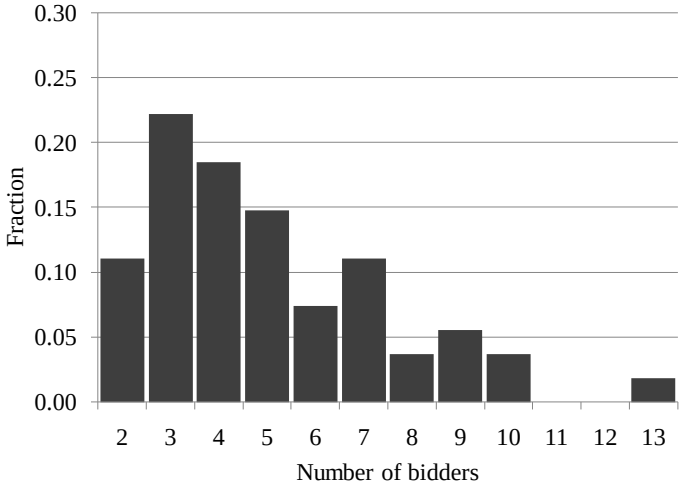


Table 2. Country coverage

	Number of contracts	Number of bids
Congo	1	7
Congo, Dem. Rep.	3	13
Ethiopia	9	36
Ghana	6	31
Kenya	4	15
Madagascar	3	21
Malawi	3	11
Mozambique	8	55
Nigeria	8	46
Tanzania	4	16
Uganda	3	11
Zambia	2	8
Total	54	270

Even though the competition effect is fully exploited and the procurement costs are intended to be minimized at the time of contract award, it is still of great concern to governments that actual payments may not be the same as the original contract. Some contract terms and specifications may be modified for technical reasons in the course of project implementation (e.g., Kapstein and Oudot, 2009). In principle, the contract amount can be changed upward and downward. Nonetheless, our data indicate that the majority of road contracts were adjusted upward, meaning that ex post cost overruns or ex ante cost underestimation happened. 37 out of 54 contracts experienced some cost overruns (Table 3). Although a majority of the revisions were less than 2 percent of the original contract amount, some contracts experienced more than 15 percent of cost adjustments.

Table 3. Ex post cost adjustments

% of original contract	Number of contracts
Adjustment < –5%	2
–5% < Adjustment < –2%	3
–2% < Adjustment < 0%	9
No adjustment	3
0% < Adjustment < 2%	19
2% < Adjustment < 5%	7
5% < Adjustment < 15%	5
Adjustment > 15%	6
Total	54

The difference between the original contract and actual payment looks minimal at least on average. The average bid price relative to the engineering cost estimate is 1.22, while the amount of actual payments is 1.25 (Table 4). Figure 2 compares the probability distributions of the normalized bids and actual payments. The distribution of the actual payments appears to concentrate slightly on the higher tail, though there is no clear statistical evidence that the two variables would be drawn from the same sample distribution.[5] Notably, the bidders' participation decision appears to be related to the likelihood of post-award amendments. A greater number of companies applied for public contracts where the contracted costs turned out overoptimistic or underestimated (Figure 3). The average number of bidders is 5.9 for contracts that experienced more than 2 percent upward adjustments in the contract amount. In the case of contracts with smaller or no amendments, the number of bidders averages only about 4.5. Hence, the (anticipated) likelihood of contract amendments seems to affect the bidders' entry behavior and thereby bidding strategy.

Table 4. Bid price and actual payment

Variable	Obs	Mean	Std. Err.
Normalized bid price	54	1.217	0.053
Normalized actual payment	54	1.245	0.057

[5] Formally, the standard t-test cannot reject the hypothesis that the means are the same; the test statistic is –0.69. The medians also seem to be different; the Pearson chi-square test statistic is 0.148. The two variables are less likely to be drawn from the same sample distribution; the Wilcoxon signed-rank test statistic is 0.243, which is statistically insignificant. Needless to say, these figures do not control any other heterogeneity in projects and bidders nor the possible endogeneity bias caused by bidder entry. The following empirical analysis will address these issues.

Figure 2. Probability distribution function of normalized bids and actual payments

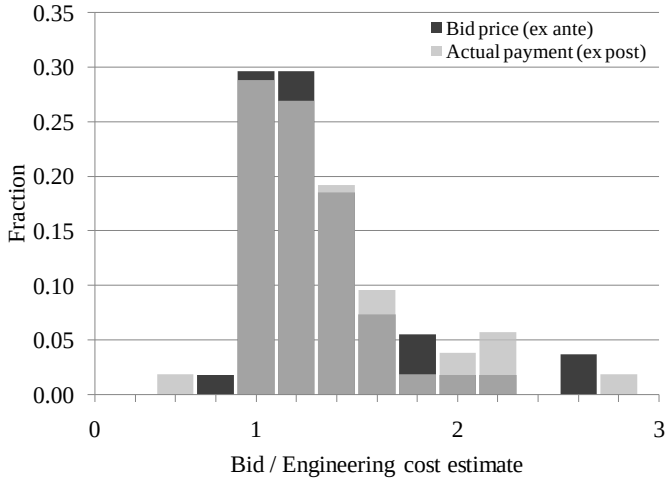
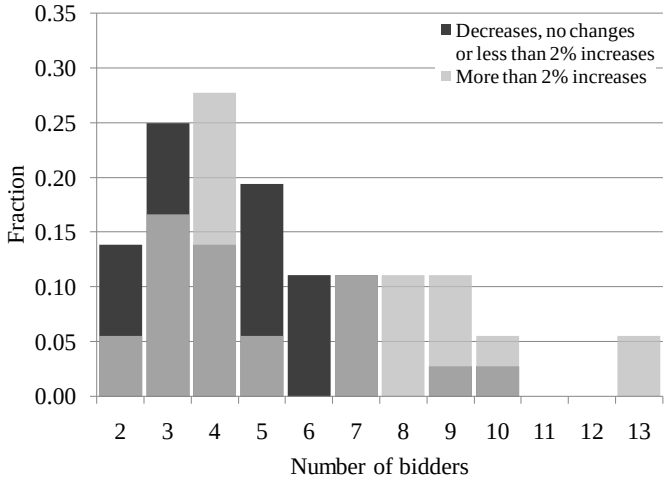


Figure 3. Probability distribution function of the number of bidders by ex post cost adjustments



IV. BASIC SETUP OF COMPETITIVE BIDDING WITH PRIVATE AND COMMON VALUES

Following Goeree and Offerman (2003) and De Silva *et al*. (2008), a simple government procurement auction with both private and common values incorporated is considered.[6] Suppose that n bidders are competing for a public work contract in a first-price sealed bid auction. Each bidder $i=\{1,\ldots,n\}$ has a private cost component c_i, such as personnel expense,

[6] The following model basically follows De Silva *et al*. (2008) but incorporates a concept of ex post adjustments from Bajari *et al*. (2006). See those works for further details.

which is assumed to be identically and independently distributed according to a density probability distribution function $f(c)$ over $c \in [c_L, c_H]$. In addition, there is a common value component *V*, which includes ex post cost adjustments and other common value of the project. The true common value is defined by the average of bidders' estimates plus a constant adjustment term, *adj*. No bidder is assumed to know the true common value ex ante. Rather, each bidder is given an unbiased estimate, $adj + v_i$, of the true common value, and v_i is assumed to be identically and independently distributed according to a density probability distribution function $g(v)$ over $v \in [v_L, v_H]$.

In this setting, the bidder *i*'s payoff function is written by:

$$\pi_i = \begin{cases} b_i - c_i + (adj + \frac{1}{n}\sum_{i=1}^{n} v_i) & \text{if } b_i = \min_{j \in n}\{b_j\} \\ 0 & \text{otherwise} \end{cases} \qquad (1)$$

where b_i is bidder *i*'s bid price. Letting bidder *i*'s private cost parameter be $s_i = c_i - adj - v_i/n$, the symmetric equilibrium bid strategy of bidder *i* who is faced with $n-1$ opponents is:

$$B_{n-1}(s_i) = E_{n-1}[c - adj - V | s_i = x, Y_1 = x] + E_{n-1}[y_1 - Y_1 | s_i = x, Y_1 = x] \qquad (2)$$

where Y_1 is the lowest cost parameter among all bidders, i.e., $Y_1 = \min_i\{c_i - adj - v_i/n\}$ and y_1 is the lowest cost parameter among rivals, i.e., $y_1 = \min_{j \neq i}\{c_j - adj - v_j/n\}$. The equilibrium strategy tells that the bid strategy is composed of two parts: bidder *i*'s expected total cost and some information rents. The latter explains how much a bidder shades its bid based on its faced uncertainty about rivals' costs. Therefore, the bidder's strategy is not only dependent on its own cost parameters but also its rivals' relative (dis)advantages in the cost structure.

Equation (2) also implies that the equilibrium bid must reflect ex post cost adjustments. In this model, it is assumed that the constant common cost component is perfectly anticipated, as in Bajari *et al*. (2006). This perfect foresight assumption may look to have discarded the question on common uncertainty about ex post cost adjustment. However, as described in the previous section, it seems to be commonly believed by contractors that even large amendments would be allowed after the contract award.

From the institutional point of view, the public procurement procedures to allow ex post adjustments may differ, depending on the size of amendments. For instance, the World Bank Guidelines require borrowers to seek the World Bank's prior approval of any extension, change order or modification of the contract if such changes would in aggregate increase the original amount of the contract by more than 15 percent of the original price.[7] Otherwise, borrowers can freely negotiate and agree on smaller change orders with contractors, though still obliged to furnish a copy of all amendments to the contract to the World Bank. In this specific case, one may hypothesize that the effects of a more than 15 percent adjustment ($adj_{>15\%}$) and less than 15 percent one ($adj_{<15\%}$) are different. The intuitive reason is that for small amendments, the adaptation costs for contractors would be relatively small and thus the impact on the bids would be limited. Alternatively, one may consider that small adjustments would be considered as stochastic in the sense that they could be positive or negative with a mean of zero (see Table 2). On the other hand, if large post amendments are anticipated, the equilibrium bid strategy would be affected. Large contract changes may presumably be costly for contractors, and such anticipated changes may induce opportunistic behavior in bidding firms.

To test this hypothesis, the following specification is examined:

$$adj = \theta_1 adj_{>15\%} + \theta_2 adj_{<15\%} \qquad (3)$$

[7] See the World Bank's *Guidelines: Procurement under IBRD Loans and IDA Credits*, Appendix 1, Clause 2.3.

where θ_1 and θ_2 are parameters to be estimated. Theoretically, the coefficients can take any value from negative to zero and positive. Five possibilities exist: First, if θ is equal to –1, it can be interpreted to mean that ex post adjustments are perfectly foreseen and incorporated into the original bids.[8] In this case, no implicit cost of adaptation is incurred because all the adjustments are fully translated into the bids.

Second, if θ is smaller than –1, it means that bidders would be overoptimistic even beyond the perfect foresight scenario and must be overestimating the magnitude of ex post adjustments either mistakenly or strategically. If it is strategic behavior, auctioneers have to be concerned about bidders' "low balling" and resultant massive cost overruns. Third, if θ is between –1 and zero, it means that ex post adjustments would incur some implicit costs to contractors, while the anticipated adjustments translate into the original bids. Under the perfect foresight assumption, $\theta + 1$ is considered an implicit cost of adapting post adjustments.

The fourth possibility is that θ is zero. This can simply be interpreted as evidence of no effect of ex post adjustments on the bidding strategy. Finally, if θ is positive, then the implicit adjustment cost is likely to be sizable.[9] It means that the implicit adjustment cost is greater than one dollar per each dollar of expected contract amendment, regardless of whether the change is anticipated or not. This case seems to be consistent with the existing evidence by Bajari *et al*. (2006).

[8] The adjustments will bring about additional profits for contractors and thus could help reduce their bid prices (see Equation (2)).

[9] There are other interpretations for the last two cases. For instance, if ex post adjustments are perfectly foreseen and the adaptation costs one dollar for a one-dollar adjustment, then θ will be estimated at zero because the two effects offset each other. Empirically, it is not identifiable which the case is. Therefore, the paper's interpretation should be considered as one of the possibilities.

V. ESTIMATION METHODS AND DATA

Following the earlier empirical auction literature (e.g., Porter and Zona, 1993; Gupta, 2002; Iimi, 2006; De Silva *et al*., 2008) and the above-mentioned theoretical framework, a simple symmetric equilibrium bid function is considered:

$$\begin{aligned} \ln BID &= \theta \ln ADJ + \alpha \ln NUM + X'\beta + \varepsilon_1 \\ &= \theta_1 D_{>15\%} \ln ADJ + \theta_2 (1 - D_{>15\%}) \ln ADJ + \alpha \ln NUM + X'\beta + \varepsilon_1 \end{aligned} \quad (4)$$

where *BID* is the evaluated bid amount. Notably, the dependent variable *BID* includes both winning and losing bids, which are considered equally informative as far as the symmetric strategy is concerned in the first-price sealed-bid auction format. *ADJ* is the amount of ex post adjustments in aggregate.[10] $D_{>15\%}$ is a dummy variable, which is set equal to one when ex post adjustments exceed in total 15 percent of the original contract.

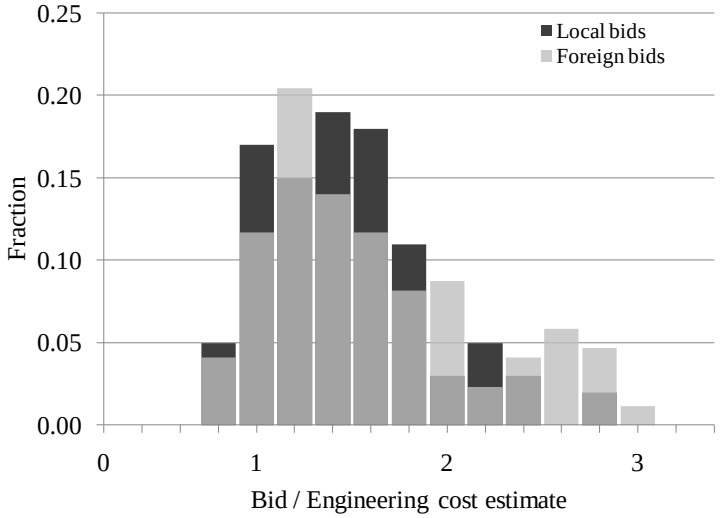
NUM represents the number of participating bidders in the price competition. This is included as a logarithmic form, because it is known that the mapping between winning bids and the number of bidders is never linear (Rezende, 2005) and the logarithmic model can capture the decreasing marginal effect of competition, which is often observed in empirical auction data.

X is a vector of contract-specific characteristics, bidder's cost variables, and its rival's cost conditions. For project-specific observables, it includes the length of roads in kilometers (*LENG*), width of roads in meters (*WIDT*) and engineering cost estimates (*COST*). To control country-specific unobservables, project country dummy variables are used. Bidder nationality dummies are also included to control for heterogeneity among bidders. In international competitive bidding, bidder nationality seems to be among the most important bidder characteristics. In our sample, foreign bidders may have the relative cost advantage to

[10] In case the amount of adjustment is zero or negative, it is replaced with a very small positive number to avoid logarithms of zero.

certain extent in Africa; the normalized foreign bids appear to be distributed slightly on the higher tail (Figure 4). But on average, local bids are lower. While local enterprises usually have comparative advantage in labor costs, multinational companies have more experiences of similar development projects and are familiar with advanced technology.

Figure 4. Probability distribution function of normalized local and foreign bids



The bidding behavior must be dependent on each bidder's production capacity and work backlog as well. Following Porter and Zona (1993), Bajari *et al*. (2006) and De Silva *et al*. (2008), two variables are included in *X*: capacity utilization rate (*UTIL*) and bidding success rate (*SUXS*). The former is defined by dividing the amount of backlog work to which each contractor is already devoted by the maximum of backlog observed during the sample period. The backlog in the sample market is calculated based on the contract amount awarded and the estimated project schedule. *SUXS* is the rate of each bidder's winning the past tenders in the sample. For those who have never been awarded, *UTIL* and *SUXS* are simply defined as nearly zero.[11]

In general, the long backlogs of work can be considered disadvantageous for firms, because the marginal cost of embarking upon an additional work would be high when they are

[11] They are set at a very small positive number to avoid logarithms of zero.

already engaged in a number of similar infrastructure projects. Firms may be devoting a large part of their financial and technical resources to the existing contracts, and they might be too busy to apply for new public works (e.g., Bajari *et al*., 2006). On the other hand, the success rate is considered advantageous because it would reflect the extent to which each contractor has been efficient at least in the past. Incompetent firms could not and should not have accumulated much experience in the past. In addition, from the auctioneer point of view, the accumulated past wins are also preferable; in the current standard public procurement systems, because companies with little award experience would likely be disqualified.

Since we consider the framework with both private and common values taken into account, the rival's minimum utilization rate (*RUTIL*) and maximum success rate (*RSUXS*) are also included in *X*. Note that these will capture some information rents (see Equation (2)). In equilibrium, each bidder can benefit more if the rival's utilization rate is high or if the rival's success rate is low, because it means that opponents would likely be occupied or inexperienced in bidding and undertaking the public contracts.

An important empirical issue in estimating Equation (4) is endogeneity of the number of bidders. Although our theoretical model assumes the conventional fixed-*n* framework, it may be determined endogenously how many bidders participate in each auction. Thus, the Ordinary Least Squares (OLS) regression might be biased (e.g., De Silva *et al*., 2003; Li and Perrigne, 2003; Li and Zheng, 2006; Ohashi, 2008). To deal with this problem, an instrumental variable technique is used. The number of bidders is instrumented by *Z*:

$$\ln NUM = X'\beta + Z'\gamma + \varepsilon_2 \qquad (5)$$

Two types of exogenous variables uncorrelated with the error term ε_1 are used.[12] First, the number of prequalified bidders is adopted (*NUMQ*). If this is not available, the number of

[12] An alternative may be the information of each bidder's backlog works, which can represent how busy that company is and thus how high its marginal cost of undertaking an additional work contract. However, this information is already included in *X* in our case, which is also used as an instrument.

firms that purchased the bidding documents is used instead. The idea behind this is the same as the use of the number of plan holders in De Silva *et al*. (2008). Undoubtedly, *NUMQ* is closely related to the number of actual bidders, because it reflects the maximum number of contenders that could appear in an auction. But this variable is not directly related to the bidding strategy, because some qualifiers can still decide not to enter the price competition.[13] In our ODA-financed procurement context, more important, the number of prequalified applicants is supposed to be known commonly by tenderers; the prequalification result is normally required to be published. Therefore it is given at the time of price bidding.[14]

The second set of instruments represents governance. One of the earlier perception-based assessments of country governance in Bolivia shows that 87 percent of surveyed enterprises indicate that the public tendering process was not clean enough (Villegas *et al*., 1998). Another recent survey of private sector's perception of public procurement reforms in Nigeria indicates that good governance would be important to enhance bidder participation; about 60 percent of respondents answered that they decided not to submit their expressions of interest in recent public tenders, because they did not trust the selection process (World Bank, 2008).[15] It is also shown that delays in payments of more than six months are another source of concern, which constitutes governance in the public sector (see below government effectiveness). All the indications are that governance is a key to curb corruption and promote competition.

We borrow governance indices from the Worldwide Governance Research Indicators database developed by Kaufmann *et al*. (2008), which covers six dimensions of governance:

[13] In our sample, the average of *NUMQ* is about 10.77, while the number of actual bidders (*NUM*) is 4.69 (see Table 3). Apparently, some potential contractors decided to not enter the market, possibly because of the technical and financial requirements and the observed intensity of competition.

[14] Even if prequalification does not take place or the result is not formally published, potential bidders may share a good sense of how many rivals would be interested in participating in the price competition through negotiation and communication for coalitional bidding.

[15] There is a general perception that contracts would be predetermined and awarded by paying a bribe; about 65 percent of respondents claimed that they did not pay any unofficial fee to win government contracts. About 40 percent of the respondents felt that government procurement policies and procedures favor only the large and medium firms. About one-third of the respondents claimed to have paid 10 percent or more as a "contract fee."

voice and accountability (*VOIC*), political stability (*POLS*), government effectiveness (*GOVE*), regulatory quality (*REGQ*), rule of law (*RULE*), and control of corruption (*CORR*). Governance is difficult to define and measure of course. These measures are still imperfect but among the most comprehensive proxies that are currently available. In the public procurement context, rule of law and corruption may be of particular concern in developing countries. Corruption is undoubtedly an entry deterrence factor, as discussed above. In addition, the unreliable judicial system will discourage firms from participating in public tendering, because no reasonable arbitration can be expected even if some problem occurs. To avoid further complications related to the possible endogeneity of governance, the lagged values are used in our empirical analysis; each index is defined by the three-year average score before the contract auction, and it is normalized on a scale from –2.5 to 2.5. Governance differs markedly across countries and depending on aspects. In addition, it is noteworthy that these indices are country-specific but not auction-invariant.

Table 5 presents the summary statistics of all these variables. It separates the sample by the amount of total adjustments. Recall that the World Bank Guidelines require borrowers to obtain the Bank's preapproval of 15 percent or more of order changes as a significant contract amendment. By definition, the amount of amendments is smaller for the public contracts involving less than 15 percent amendments. Another clear difference between the two subsets may be in the number of bidders. More firms participated in the competition for contracts that would end up requiring significant cost adjustments. This may be an indication that some information on ex post adjustments might be anticipated beforehand. In other technical terms, there is no clear difference between the two groups.

Table 5. Summary statistics

Variable	Abbr.	Less than 15% adjustments					More than 15% adjustments				
		Obs.	Mean	Std.Dev.	Min	Max	Obs.	Mean	Std.Dev.	Min	Max
Bid amount 1/	*BID*	225	21.82	18.09	0.63	86.35	45	15.85	14.51	2.09	48.66
Total amount of ex post adjustments 1/	*ADJ*	48	0.31	0.75	-2.33	2.80	6	10.81	14.40	0.61	38.40
Length of roads (km)	*LENG*	48	59.89	53.82	2.95	246.00	6	50.60	65.64	7.00	176.00
Width of roads (m)	*WIDT*	48	7.15	2.23	5.00	21.00	6	9.07	5.98	3.00	20.00
Engineering cost estimate 1/	*COST*	48	16.44	15.96	0.78	70.82	6	12.68	10.48	1.64	29.14
Utilization rate	*UTIL*	225	0.22	0.35	0.00	1.00	45	0.16	0.32	0.00	1.00
Success rate	*SUXS*	225	0.12	0.25	0.00	1.00	45	0.02	0.06	0.00	0.25
Minimum rival utilization rate	*RUTIL*	225	0.04	0.16	0.00	1.00	45	0.00	0.01	0.00	0.08
Maximum rival success rate	*RSUXS*	225	0.34	0.36	0.00	1.00	45	0.10	0.12	0.00	0.25
Number of bidders	*NUM*	48	4.69	2.04	2	10	6	7.50	4.04	2	13
Number of prequalified contractors 2/	*NUMQ*	48	10.77	6.00	2	25	6	14.83	5.95	6	21
Voice and accountability (average over the past 3 years)	*VOIC*	48	-0.60	0.50	-1.67	0.16	6	-0.35	0.30	-0.74	-0.12
Political stability (average over the past 3 years)	*POLI*	48	-0.89	0.80	-2.48	0.16	6	-0.54	0.95	-1.79	0.16
Government effectiveness index (average over the past 3 years)	*GOVE*	48	-0.73	0.37	-1.69	-0.16	6	-0.58	0.35	-1.03	-0.12
Quality of regulation (average over the past 3 years)	*REGL*	48	-0.65	0.50	-1.69	0.02	6	-0.55	0.50	-1.25	-0.08
Rule of law index (average over the past 3 years)	*RULE*	48	-0.80	0.48	-1.86	-0.07	6	-0.91	0.52	-1.52	-0.11
Control-of-corruption index (average over the past 3 years)	*CORR*	48	-0.79	0.41	-1.49	0.09	6	-0.85	0.46	-1.39	-0.21
Project delays (month)	*DLAY*	48	2.61	4.92	0.00	21.00	6	12.60	7.65	0.00	23.60

1/ In millions of constant 2007 U.S. dollars.

2/ In case such information is not available, the number of contractors who purchased the bidding documents is used instead.

VI. ESTIMATION RESULTS AND POLICY IMPLICATIONS

First, the ordinary least squares (OLS) regression is performed (Table 6). The effect of the anticipated ex post adjustments remains ambiguous; the coefficients associated with *ADJ* are all negative but statistically insignificant. However, these figures may be biased because an explanatory variable, the number of bidders, might be endogenously determined and is not controlled in the OLS estimation.

In the instrumental variable (IV) estimation, the coefficient of $ADJ_{>15\%}$ is found significant at –0.008, while $ADJ_{<15\%}$ still has a statistically insignificant coefficient. Thus, if any large post-award amendments are anticipated, bidders are likely to reduce their bids systematically. For minor adjustments, there is no conclusive evidence. The magnitude of the estimated impact of large adjustments is quantified by the delta method evaluated at the sample means:

$$\Delta BID = \exp(\hat{\theta}_1 \ln(\overline{ADJ} + 1) + \overline{X}'\hat{\beta}) - \exp(\hat{\theta}_1 \ln(\overline{ADJ}) + \overline{X}'\hat{\beta}) \quad (6)$$

It assumes a one-dollar increase in adjustments after the contract award, conditional on the total amount of adjustments greater than 15 percent of the original contract. Based on the fourth column model of Table 6, the marginal effect is estimated at –0.07 with a standard error of 0.03. This is statistically different from zero; hence, the impact exists and the anticipated adjustment would likely reduce the bids by 7 cents at the time of tendering. In addition, the effect is also significantly different from –1; thus, even if a one-dollar change is expected, bidders would not discount their bids by one dollar but only 7 cents. The gap is interpreted as an implicit adaptation cost. This finding is consistent with our third scenario in Section III. That is, ex post adjustments incur some implicit adaptation costs to contractors, while the anticipated adjustments per se translate into the bid prices. Under the perfect foresight assumption, the evidence means that the effect of ex post adjustments is mostly offset by the incurred adaptation cost, which is estimated at about 93 cents per one dollar of contract adjustment. Thus, it is costly but to a lesser extent than the case of U.S. highway auctions where it is estimated at 2.7 dollars (Bajari *et al.*, 2006).

Table 6. OLS and IV bid regressions

Estimation method	OLS	OLS	IV	IV	IV	IV
ln*ADJ* (θ)	−0.0012		−0.0011			
	(0.0019)		(0.0019)			
ln$ADJ_{>15\%}$ (θ1)		−0.0065		−0.0080 *		
		(0.0050)		(0.0049)		
ln$ADJ_{<15\%}$ (θ2)		−0.0007		−0.0005		
		(0.0020)		(0.0020)		
ln*DLAY*					0.0052	
					(0.0039)	
ln$DLAY_{>1\ year}$						0.0079 *
						(0.0044)
ln$DLAY_{<1\ year}$						−0.0353
						(0.0298)
UTIL	−0.112 *	−0.114 *	−0.089	−0.095 *	−0.098 *	−0.099 *
	(0.059)	(0.059)	(0.058)	(0.058)	(0.052)	(0.053)
SUXS	0.032	0.021	0.0004	−0.011	−0.0135	−0.005
	(0.105)	(0.108)	(0.113)	(0.116)	(0.099)	(0.100)
RUTIL	0.054	0.055	0.193 *	0.181	0.151	0.166 *
	(0.093)	(0.096)	(0.115)	(0.117)	(0.096)	(0.099)
RSUXS	−0.001	−0.027	−0.089	−0.113	−0.072	−0.069
	(0.087)	(0.093)	(0.097)	(0.102)	(0.085)	(0.085)
ln*NUM*	0.001	0.015	0.184 **	0.184 **	0.158 **	0.165 **
	(0.054)	(0.057)	(0.094)	(0.094)	(0.077)	(0.077)
ln*LENG*	0.079 *	0.091 *	0.057	0.074	0.047	0.041
	(0.049)	(0.050)	(0.048)	(0.049)	(0.043)	(0.042)
ln*WIDT*	0.034	0.030	0.220	0.197	0.263	0.306
	(0.183)	(0.189)	(0.215)	(0.222)	(0.192)	(0.194)
ln*COST*	0.895 ***	0.891 ***	0.889 ***	0.884 ***	0.875 ***	0.877 ***
	(0.042)	(0.042)	(0.043)	(0.043)	(0.036)	(0.036)
Constant	1.385 **	1.384 *	0.919	0.965	1.257 **	1.194 **
	(0.697)	(0.720)	(0.781)	(0.815)	(0.603)	(0.598)
Obs.	270	270	270	270	270	270
Adj. *R*-squared	0.956	0.957	0.955	0.955	0.964	0.964
F-statistics	357.54	345.46	325.19	300.84	362.95	450.28
Number of dummy variables:						
Recipient countries	10	10	10	10	10	10
Bidder nationality	29	29	29	29	29	29

Note that the dependent variable is the log of the bid. The robust standard errors are shown in parentheses. *, **, and *** indicate the 10%, 5% and 1% significance levels, respectively.

When evaluating the estimated bid function under the assumption of no adjustment anticipated, the average bid amount is estimated at US$0.199 million per kilometer (km) (Table 7). Conditional on an average large-scale amendment anticipated, the predicted bid would decline to US$0.178 million per km with a 95 percent confidence interval between US$0.158 million and US$0.198 million. Therefore, even under the perfect foresight assumption, the bids that undercut this range could be considered to be statistically unlikely. Of course, these figures evaluate the bid function at the sample means for other explanatory variables, meaning that different work specifications would have different cost predictions.

But on average, the result can be interpreted to mean that bids are unrealistically low if they fall below US$0.158 million per unit, which is the lower bound of the 95 percent confidence interval of the predicted unit price in our case.

Table 7. Predicted bid amount per km

Assumption	Bid/km	Std.Err.	95% confidence interval
With no adjustment anticipated	0.199	0.004	0.191 - 0.208
With large adjustment anticipated	0.178	0.010	0.158 - 0.198

In millions of U.S. dollars.

The main policy implications are straightforward. Based on the estimated bid function, it is possible to detect statistically unlikely bids that might follow the strategic low balling strategy. If this is the case, governments should pay particular attention to the substantial responsiveness of bids or bidders during the bid evaluation process. It is also clear that if governments continue to allow massive cost overruns in public road procurement, a considerable amount of adaptation costs would be required from contractors and bidders will incorporate that cost into their bids. After all, it will be the cost to the governments, whence taxpayers or citizens.

To mitigate such a risk, there are several measures to tighten incentive contracts and improve the solidity of budget formulation and execution. First, governments can explicitly strengthen contract enforceability. In the defense procurement market, for instance, the French government has reinforced a responsibility principle that those who are responsible for cost overruns should pay for themselves (Kapstein and Oudot, 2009). In highway contracts in the State of Minnesota, the explicit time incentives recently began to be given to contractors to prevent their opportunistic delays (Bajari and Lewis, 2009).

Second, in particular in the ODA context, output-based aid (OBA) is one possible measure to impose stronger cost incentives to contractors (or operators). In OBA, unlike traditional approaches, the payments of aid are linked to the delivery of specific services or outputs. Given the pre-agreed specific policy targets, a fixed amount of aid, which aims to subsidize a fraction of the cost of particularly noncommercial development activities, would be disbursed

only after those outcomes are proven accomplished (GPOBA, 2008). Clearly, this fixed payment arrangement

Conversely, third, governments can also choose to make a contract more flexible in advance so that any modifications would be allowed at a lower cost. Periodical benchmarking of public contracts, both in terms of price and quality, against market comparators, may help smoother adjustments, as implemented in the United Kingdom. Half of public finance initiative (PFI) projects involve systematic benchmarking to assess the value for money during project implementation, though the usage of such a mechanism still seems challenging (NAO, 2001).[16]

One important policy question may be what the main sources of the implicit adaptation costs are. Project delays are obviously one of them. When the cost adjustment variable is replaced with a variable that represents the length of project delays in months (*DLAY*), it can be shown that massive project delays would add greatly to the bid prices, while smaller delays may not impact on the bids (see the last two column models in Table 6). The elasticity of the bids with respect to delays is significantly positive at 0.0079, conditional on more than one year of delays. Hence, overoptimistic project schedule and anticipated project delays would inflate the equilibrium bids and thereby public procurement costs in the road sector. When the last column model is evaluated at the sample means, an additional one-month delay in project completion would cause a marginal cost of 23,530 dollars. Therefore, in addition to the accuracy of project cost estimates, it is also important to agree on a reasonable schedule for a contracted work and make it high-powered incentives to contractors.

Other than the adjustment effects, the estimated bid function reveals that larger projects in terms of technical scope are more costly. Not surprisingly, the engineering cost estimate is significant. Longer roads also seem to be more expensive. The number of bidders has a significant, positive coefficient in the IV regressions of Table 6, possibly reflecting the

[16] Despite the prevalence of the mechanism, only eight of the 54 public procurement authorities have actually made use of it.

winner's curse. Of particular note, this is the consistent result after the possible endogeneity of bidder participation is controlled. The Hausman exogeneity test shows that the number of bidders is likely endogenous. The chi-square test statistics are estimated at 8.10 and 6.78 for the third and fourth column models, compared with the corresponding OLS models.

The estimation results also indicate that contractors are resource-constrained to the extent that the bids would increase if they have higher capacity utilization rates. The coefficient of *UTIL* has been found consistently negative, meaning that busier contractors would be less competitive in the market. Conversely, *RUTIL* may have a positive coefficient; if rival firms are swamped with a long backlog of works, that would bring some additional advantage, thereby creating rents. The maximum rival's success rate also has a consistent sign to our prior expectation, though not significant. In the presence of presumably efficient opponents, bidders have to cut their prices because their cost advantage would likely diminish. The success rate may have a positive coefficient (as expected), but it does not seem to be statistically robust.

To see robustness in our estimates, a two-stage least-squares (2SLS) estimation is also performed, using a zero-truncated negative binomial (ZTNB) model as the first stage regression. Note that the number of bidders is a nonnegative integer and typical of count data (e.g., Li and Perrigne, 2003; Ohashi, 2008). In this case the dependent variable is the number of bidders, *NUM*, without taking the log. With the number of bidders replaced with the predicted number of bidders based on the negative binomial model, the bid function is reestimated through a 2SLS technique (Table 8). Not surprisingly, the results are found broadly consistent with the above IV estimator. Anticipated large adjustments would increase the bids with some implicit adaptation cost incurred to bidders. The longer backlogs, the higher bids. If rivals have higher success rates, bidders would have to be more aggressive because of their diminishing cost advantage. Finally, the bid would increase with the number of bidders.

The quantile regression is also used to examine the potentially heterogeneous bidding behavior across levels of bids (De Silva *et al*., 2003). While means, thereby the OLS regression, are sensitive to possible outliers, the quantile regression allows to estimate differences in the distribution of entrant bids more accurately. Notably, however, the quantile technique, even if differencing in quantile regression, cannot solve the endogeneity problem in bidder participation (Arias *et al.*, 2001). Therefore, the two-stage quantile regression (2SQR) estimation is performed. Five quantiles are examined to explore the difference across bids: .10 .25, .50, .75 and .90.

The 2SQR seems to have captured relatively large adaptation costs in smaller contracts. The estimated coefficient of $ADJ_{>15\%}$ is smaller in the higher tail, i.e., at the 75th and 90th percentiles (Table 8).[17] When holding everything else constant, it means that the implied cost of adapting post adjustments would be smaller in large contracts. Recall that the implicit adaptation cost is calculated by $\hat{\theta}_1 + 1$ under the perfect foresight assumption. For small contracts, the anticipated ex post adjustments would largely be offset by the implicit adaptation cost. At the 10th and 25th percentiles, the former may even be dominated by the latter; thus, the coefficient is found positive in these two cases. The results can be interpreted as an indication that large ex post adjustments would be more difficult to accommodate in smaller work contracts. The possible reason is that small work contractors normally have little bargaining power and sometimes have to bear the cost of adjustments that they are not directly responsible for. By contrast, contractual changes could be accommodated relatively easily in large-scale contracts; contractors may have larger bargaining power, and there may be plenty of room to incorporate unexpected order changes.

In addition, the equilibrium bid has been found to increase with the capacity utilization rate, especially in large contracts. It seems natural that the bidders' capacity would matter when they attempt to undertake a new large work. The results show that the success rate may be advantageous to bidders, as expected; the two specifications have a significant coefficient.

[17] The coefficient is negative and *large* in absolute terms in a higher tail.

RUTIL also has a significant, positive coefficient in the lower tail; the coefficient is estimated at about 0.3. When rival firms are busy, the equilibrium bid would increase, reflecting some informational rents. The effect of the maximum rival's success rate remains inconclusive; it can be positive and negative.

Table 8. Two-stage least squares and two-stage quantile least squares regressions on bids

Finally, the first stage regressions reveal several important findings about how firms decide to participate in competitive bidding (Table 9). The negative binomial regression generated a broadly consistent result with the first-stage regression of IV models. First, it is shown that the greater number of bidders would participate in an auction if more companies applied for prequalification or purchased the bidding documents. This is natural. Second, good governance could encourage more firms to enter the market. Especially, rule of law and

anticorruption policies appear to be essential. The coefficients of *RULE* and *CORR* are always found positive and significant. The evidence looks supportive of a survey result in Nigeria (World Bank, 2008). The effectiveness of governments may also be important, but the coefficient of *GOVE* is not statistically significant in the IV models.

Interestingly, the evidence indicates that more bidders would participate when large ex post adjustments are anticipated. The coefficient of $ADJ_{>15\%}$ is found significantly positive. This is another piece of evidence that public work contracts would not be binding in the road sector in Africa. It seems to be commonly believed that significant cost adjustments would take place, which will bring additional revenues, whence profits, to contractors, whence motivating them to enter the market. In addition, the bidder's entry decision seems to be affected strongly by its opponent characteristics. Particularly, bidders may prefer to participate in public tenders where some strong competitors who succeeded in winning past contracts are also participating. One of the possible interpretations is that bidding firms would follow the past successful contractors' behavior as an indicator of the expected profitability of a work being contracted, although price competition against such strong opponents might turn out hard later on.

Table 9. Negative binomial and least-squares regressions on the number of bidders

Estimation method	Zero truncated negative binomial		1st stage regression for IV models	
ln*ADJ* (θ)	0.0005		0.0025	
	(0.0035)		(0.0022)	
ln$ADJ_{>15\%}$ ($\theta 1$)		0.024 **		0.010 ***
		(0.009)		(0.004)
ln$ADJ_{<15\%}$ ($\theta 2$)		0.0008		0.0020
		(0.0034)		(0.0022)
UTIL	0.397 *	0.337	−0.050	−0.044
	(0.237)	(0.222)	(0.046)	(0.046)
SUXS	−0.407	−0.411	0.121	0.139 *
	(0.273)	(0.301)	(0.075)	(0.075)
RUTIL	−0.330	−0.480	−0.599 ***	−0.571 ***
	(0.304)	(0.312)	(0.120)	(0.120)
RSUXS	0.724 ***	0.865 ***	0.480 ***	0.515 ***
	(0.166)	(0.190)	(0.065)	(0.066)
ln*LENG*	−0.012	−0.056	0.053	0.036
	(0.106)	(0.094)	(0.041)	(0.042)
ln*WIDT*	−1.097 ***	−0.791 ***	−1.162 ***	−1.101 ***
	(0.321)	(0.309)	(0.139)	(0.140)
ln*COST*	0.118	0.094	0.026	0.023
	(0.081)	(0.065)	(0.043)	(0.043)
NUMQ	0.120 ***	0.121 ***		
	(0.029)	(0.027)		
ln*NUMQ*			0.660 ***	0.678 ***
			(0.060)	(0.060)
VOIC	0.527	−0.159	−2.219 **	−1.901 **
	(1.295)	(1.441)	(0.889)	(0.889)
POLI	−4.766 *	−2.680	1.597	1.383
	(2.578)	(2.673)	(1.443)	(1.431)
GOVE	−10.963 ***	−7.588 *	−0.089	−0.145
	(4.129)	(4.233)	(1.985)	(1.964)
REGL	6.120 ***	3.865 **	1.173	0.827
	(1.964)	(1.956)	(0.789)	(0.794)
RULE	5.533 ***	6.106 ***	5.007 ***	4.953 ***
	(1.580)	(1.568)	(0.849)	(0.840)
CORR	3.063 ***	2.588 **	1.176 **	1.128 **
	(1.323)	(1.201)	(0.496)	(0.491)
Constant	−5.342	−0.363	2.358 **	2.209 **
	(7.455)	(7.653)	(1.009)	(1.000)
Obs.	54	54	270	270
Wald chi2 statistics	10369.65	4236.97		
Adj. R-squared			0.807	0.811
F-statistics			21.87	22.04
Number of dummy variables:				
Recipient countries	9	9	10	10
Bidder nationality	9	9	29	29

Note that The dependent variable is the number of bidders for the zero truncated negative binomial model and the log of the number of bidders for the 1st stage of IV estimation. The robust standard errors are shown in parentheses. *, **, and *** indicate the 10%, 5% and 1% significance levels, respectively.

VII. CONCLUSION

The paper readdresses the post-award adjustment problem in infrastructure procurement. Cost overruns and project delays have long been chronic difficulties in implementing infrastructure projects. Certain adjustments after the contract award may be unavoidable in large infrastructure contracts, especially when they take more than several years to complete. Some contract terms and specifications may have to be modified for technical reasons in the course of project implementation.

However, too many ex post adjustments would not only incur significant adaptation costs to contractors but also undermine efficiency, credibility and predictability of the public spending. If the “low balling” strategy is allowed, the risk of choosing inefficient contractors would be enormous and thus result in higher public procurement costs. In particular in Africa, governments are faced with severe resource constraints, while there are a number of projects that they have to finance. If massive cost overruns and project delays continue to be allowed, the original expenditure prioritization policy would be distorted.

The paper examines the case of public road procurement in Sub-Saharan Africa. About 70 percent of road contracts experienced some cost overruns. The evidence indicates that if large post-award amendments are anticipated, bidders are likely to reflect them to their bids systematically. Under the perfect foresight assumption, one dollar of contract adjustment would decrease the equilibrium bid strategy by 7 cents, because of the cost of adapting ex post adjustments. Based on this, the incurred implicit adaptation cost is estimated at 93 cents per one dollar of contract adjustment. Thus, the ex post adaptation approach is concluded to be costly and governments should avoid unnecessary cost overruns and delays.

In order for governments to detect possible low balling bids at the time of bidding, the estimated bid function can provide a certain guidance. In our specific case, a threshold is estimated at US$0.158 million per km. On average, if a bid falls below this, it is considered statistically unlikely; governments should reconsider the bids’ responsiveness carefully. Then,

governments could and should tighten incentive contracts, because bids are presumed realistic and ex post adaptation cost will be significant. There is no reason for allowing ex post renegotiation, unless physically obvious change orders are called for. The work schedule should also be used as high-powered incentives to contractors. The estimation result indicates that significant project delays would inflate the equilibrium bid function. Based on these higher-powered incentive contracts, governments would be able to formulate the budget more accurately and execute it more predictably.

REFERENCE

ADB. 2006. *Prequalification of Bidders User's Guidelines,* Asian Development Bank.

Alexeeva, Victoria, Gouthami Padam, Cesar Queiroz. 2008. Monitoring road works contracts and unit costs for enhanced governance in Sub-Saharan Africa. Transport Papers TP-21, The World Bank.

Anthon, Signe, Peter Bogetoft, Bo Jellesmark Thorsen. 2007. Socially optimal procurement with tight budgets and rationing. *Journal of Public Economics*, Vol. 91, pp. 1625-1642.

Arias, Omar, Kevin Hallock, Walter Sosa-Escudero. 2001. Individual heterogeneity in the returns to schooling: Instrumental variable quantile regression using twins data. *Empirical Economics*, Vol. 26, pp. 7-40.

Bajari, Patrick, Gregory Lewis. 2009. Procurement contracting with time incentives: Theory and evidence. NBER Working Paper Series 14855. Cambridge, MA: National Bureau of Economic Research.

Bajari, Patrick, Steven Tadelis. 2001. Incentives versus transaction costs: A theory of procurement contracts. *The RAND Journal of Economics*, Vol. 32(3), pp. 387–407.

Bajari, Patrick., Stephanie Houghton, Steven Tadelis. 2006. Bidding for incomplete contracts: an empirical analysis. NBER Working Paper Series 12051. Cambridge, MA: National Bureau of Economic Research.

Blanc-Brude, Frédéric, Hugh Goldsmith, Timo Välilä. 2006. Ex ante construction costs in the European road sector: A comparison of public-private partnerships and traditional public procurement. Economic and Financial Report 2006/01, European Investment Bank.

Besley, Timothy, Maitreesh Ghatak. 2001. Government versus private ownership of public goods. *The Quarterly Journal of Economics*, Vol. 116(4), pp. 1343–1372.

Brannman, Eric, Douglass Klein, Leonard Weiss. 1987. The price effect of increased competition in auction markets. *The Review of Economics and Statistics*, Vol. 69, pp. 24-32.

Che, Yeon-Koo. 1993. Design competition through multidimensional auctions. *Rand Journal of Economics*, Vol. 24, pp. 668-680.

Cripps, Martin, Norman Ireland. 1994. The design of auctions and tenders with quality thresholds: the symmetric case. *The Economic Journal*, Vol. 104, pp. 316-326.

De Silva, Dakshina, Timothy Dunne, Georgia Kosmopoulou. 2003. An empirical analysis of entrant and incumbent bidding in road construction auctions. *The Journal of Industrial Economics*, Vol. 51, pp. 295-316.

De Silva, Dakshina, Timothy Dunne, Anuruddha Knkanamge, Georgia Kosmopoulou. 2008. The impact of public information on bidding in highway procurement auctions. *European Economic Review*, Vol. 52, pp. 150-181.

Estache, Antonio, Atsushi Iimi. 2008. Procurement efficiency for infrastructure development and financial needs reassessed. Policy Research Working Paper No. 4662, the World Bank.

Estache, Antonio, Atsushi Iimi. 2009a. Joint bidding, governance and public procurement costs: A case of road projects. *Annals of Public and Cooperative Economics*, Vol. 80, pp. 393-429.

Estache, Antonio, Atsushi Iimi. 2009b. Auctions with endogenous participation and quality thresholds: evidence from ODA infrastructure procurement. Policy Research Working Paper No. 4853, the World Bank.

Estache, Antonio, Jose-Luis Guasch, Atsushi Iimi, Lourdes Trujillo. 2009. Multidimensionality and renegotiation: evidence from transport-sector public-private-partnership transactions in Latin America. *Review of Industrial Organization*, forthcoming.

Fishe, Raymond, Preston McAfee. 1987. Nonlinear contracts, zero profits and moral hazard. *Economica,* Vol. 54, pp. 97-101.

Flyvbjerg, Bent, Mette Skamris Holm, Søren Buhl. 2002. Underestimating costs in public works projects: Error or lie? *Journal of the American Planning Association*, Vol. 68, pp. 279-295.

Flyvbjerg, Bent. 2005. Policy and planning for large infrastructure projects: Problmes, cuases, cures. Policy Research Working Paper No. 3781, the World Bank.

Foster, Vivien. 2005. Ten years of water service reforms in Latin America: toward an Anglo-French model. Water Supply and Sanitation Sector Board Discussion Paper Series No. 3, The World Bank.

Goeree, Jacob, Theo Offerman. 2003. Competitive bidding in auctions with private and common values. *The Economic Journal,* Vol. 113, pp. 598-613.

GPOBA. 2008. *GPOBA Annual Report 2008*. The Global Partnership on Output-Based Aid.

Grossman, Sanford, Oliver Hart. 1986. The costs and benefits of ownership: A theory of vertical and lateral integration. *The Journal of Political Economy*, Vol. 94(4), pp. 691–719.

Guasch, Luis. 2004. *Granting and Renegotiating Infrastructure Concessions: Doing It Right*. The World Bank.

Guasch, Luis, Jean-Jacques Laffont, Stephane Straub. 2007. Concessions of infrastructure in Latin America: government-led renegotiation, *Journal of Applied Econometrics*, Vol. 22, pp. 1267-1294.

Guasch, Luis, Jean-Jacques Laffont, Stephane Straub. 2008. Renegotiation of concession contracts in Latin America: evidence fro mthe water and transport sectors, *International Journal of Industrial Organization*, Vol. 26, pp. 421-442.

Gulati, Mohinder, M.Y. Rao. 2007. Corruption in the electricity sector: A pervasive scourge, in *The Many Faces of Corruption: Tracking Vulnerabilities at the Sector Level*, eds. by Edgardo Campos and Sanjay Pradhan, pp. 115-158. The World Bank.

Gupta, Srabana. 2002. Competition and collusion in a government procurement auction market. *Atlantic Economic Journal*, Vol. 30, pp. 13-25.

Hart, Oliver. 2003. Incomplete contracts and public ownership: Remarks, and an application to public-private partnerships. *The Economic Journal*, Vol. 113(March), pp. C69–C76.

Hart, Oliver, Andrei Shleifer, Robert Vishny. 1997. The proper scope of government: Theory and an application to prisons. *The Quarterly Journal of Economics*, Vol. 112(4), pp. 1127–1161.

Heller, Peter. 2005. Understanding fiscal space. IMF Policy Discussion Paper, PDP/05/4. International Monetary Fund.

Iimi, Atsushi. 2006. Auction reforms for effective official development assistance. *Review of Industrial Organization*, Vol. 28, pp. 109-128.

IMF. 2005. Public investment and fiscal policy—summaries of the pilot country studies. International Monetary Fund.

Kapstein, Ethan, Jean-Michel Oudot. 2009. Reforming defense procurement: Lessons from France. *Business and Politics*, Vol. 11(2), Article 1.

Kaufmann, Daniel, Aart Kraay, Massimo Mastruzzi. 2008. Governance matters VII: aggregate and individual governance indicators, 1996-2007. Policy Research Working Paper No. 4654, the World Bank.

Kessel, Reuben. 1971. A study of the effects of competition in the tax-exempt bond market, *The Journal of Political Economy*, Vol. 79, pp. 706-738.

Klein, Michael. 1998. Bidding for concessions. Policy Research Working Paper Series No. 1957, The World Bank.

Laffont, Jean-Jacques, Jean Tirole. 1993. *A Theory of Incentives in Procurement and Regulation*, Cambridge: MIT Press.

Li, Tong, Isabelle Perrigne. 2003. Timber sale auctions with random reserve prices. *The Review of Economics and Statistics*, Vol. 85, pp. 189-200.

Li, Tong, Xiaoyong Zheng. 2006. Entry and competition effects in first-price auctions: theory and evidence from procurement auctions. Cemmap working paper CWP13/06, University College London.

McAfee, Preston, John McMillan. 1986. Bidding for contracts: A principal-agent analysis. *The RAND Journal of Economics*, Vol. 17, pp. 326-338.

Milgrom, Paul, Robert Weber. 1982. A theory of auctions and competitive bidding. *Econometrica*, Vol. 50, pp. 1089-1122.

NOA. 2001. *Managing the Relationship to Secure a Successful Partnership in PFI Projects*. The National Audit Office.

Ohashi, Hiroshi. 2008. Effects of transparency in procurement practices on government expenditure: a case study municipal public works. CIRJE Discussion Paper No. 548, University of Tokyo.

Olken, Benjamin. 2005. Monitoring corruption: evidence from a field experiment in Indonesia. NBER Working Paper Series 11753.

Porter, Robert, Douglas Zona. 1993. Detection of bid rigging in procurement auctions. *Journal of Political Economy*, Vol. 101, pp. 518-538.

Rezende, L. 2005. Auction econometrics by least squares. Mimeograph. University of Illinois, Urbana-Champlain, IL.

Villegas, Ascencio, Arcadio Morales, Neil Andersson. 1998. Corruption in the public services: The view of the private sector: Key findings of the 1st national integrity survey, Bolivia, 1997-98, CIET Project Report PR-BO-bolem-98, CIET International.

Ware, Glenn, Shaun Moss, Edgardo Campos, Gregory Noone. 2007. Corruption in public procurement: a perennial challenge, in *The Many Faces of Corruption: Tracking Vulunerabilities at the Sector Level*, eds. by Edgardo Campos and Sanjay Pradhan, pp. 295-334. The World Bank.

Wolfstetter, Elmar. 1996. Auctions: an introduction. *Journal of Economic Surveys*, Vol. 10, pp. 367-421.

World Bank. 2005. *Infrastructure and the World Bank: A Progress Report*. The World Bank.

World Bank. 2008. *Procurement under World Bank-Financed Projects: FY07 Annual Report*. Operations Policy and Country Services, The World Bank.