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Enhancing Competition in Public Procurement for Sustained Growth: Applying a Double Selection Model to Road Procurement Auctions

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***Abstract*—**Limited competition has been a serious concern in infrastructure procurement. Importantly, however, there are normally a number of potential bidders initially showing interest in proposed projects. This paper focuses on tackling the question why these initially interested bidders fade out. An empirical problem is that no bids of fading-out firms are observable. They could decide not to enter the process at the beginning of the tendering or may be technically disqualified at any point in the selection process. The paper applies the double selection model to procurement data from road development projects in developing countries and shows that competition ends up restricted, because bidders are self-selective and auctioneers also tend to limit participation depending on the size of contracts.Limited competition would likely lead to high infrastructure procurement costs, threatening fiscal sustainability and economic growth.

***Keywords*—**Auction theory, endogenous bidder entry, infrastructure development, public procurement.

I. Introduction

INFRASTRUCTURE procurement is still a challenging task for developing country governments. The limited degree of competition remains among the major concerns (e.g., [1]-[3]). A fundamental problem for auctioneers, namely executing agencies, is how to contain government procurement costs while ensuring the good quality of public work would be delivered. Even though competitive bidding is now commonly required in public procurement systems, bidder participation is often limited because infrastructure projects tend to be highly valuable, complex and customized.

Traditional auction theory suggests that increased competition would lower procurement costs under the fixed-*n* approach. Although how the degree of competition would affect the auction outcome will depend on model, this has been confirmed in many empirical auctions (e.g., [3]-[6]). In the independent private value paradigm, by which the traditional ODA projects could be characterized, the winning bid should approach the lowest possible procurement price, as the number of participants in an auction increases.[1] Therefore, competition is generally considered welcome by auctioneers. The issue examined in the current paper is closely related to the results derived by [9], which discusses the value of an extra bidder in an auction in terms of the buyer's expected traded prices.

Despite its importance, the currently observed level of competition in public procurement is still undoubtedly low in most developing countries. The OECD Development Assistance Committee (DAC) member countries are spending about 12 billion U.S. dollars for assisting infrastructure projects in developing countries every year. But this is far below the estimated financial requirements. In order to sustain economic growth under the constraint, especially under the ongoing credit crunch, it is required for developing countries to utilize available aid resources more effectively and efficiently. Competition must be enhanced furthermore.

Importantly, however, bidders' participation is endogenous. On one hand, potential bidders themselves will decide whether or not to enter the tendering, depending on their endowments, rivals' behavior and the size and nature of projects being auctioned. On the other hand, auctioneers may also desire to limit competition in the sense that they might disqualify some of the initial applicants prior to taking their price bids into account. Project owners often want to exclude from the selection process those who would likely fail to fulfill the agreed contract.

Without doubt, the number of bidders observed at the final price evaluation stage results from a sequence of choices made by prospective firms and an auctioneer. For this reason, partial observability must emerge as a potential empirical problem. One can observe bids only if firms participate in the tender and

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[1] How to determination the paradigm must of necessity defer to individual empirical works (e.g., [5] and [7]). The ODA-related infrastructure project procurement auctions may be more likely to be characterized by the independent private value paradigm, because auction-specific asymmetric uncertainty among bidders plays a more important role to determine the individual bid prices than symmetric uncertainty does. Typical are labor costs of individual firms. Even though the same amount of inputs is required to implement a project, unit costs (e.g., wages and equipment prices) are different across firms [8]. Also those private factors remain different even after the contract is awarded. By contrast, political instability and regulatory credibility are considered as a commonly uncertain component. These often affect the public-private partnership (PPP) infrastructure projects. However, in our traditional ODA projects to procure only specific construction works or equipment, these are less important than firm individual cost factors. Furthermore, ODA contracts are not supposed to be resold once awarded.

are qualified through the prerequisite conditions. Auction theory has discussed the endogeneity issue associated with bidders' entry (e.g., [10]-[12]). Basically, it shows that high entry costs would reduce the optimal number of bidders, and bidders would enter until their expected profits are driven to the entry cost. Unfortunately, however, the selection is rarely singleton in practice. Auctioneers can be selective as well. Moreover, even qualified bidders may prefer to withdraw their proposal in the middle of the process for some reason, e.g. collusion.

The current paper collects data on potential bidders from public procurement auctions for road development projects in developing countries and aims at tracking their sequential decisions toward the final decision about who would be the awardee. In general, it is empirically uneasy to identify potential bidders, simply because they are not observable.[2] The current paper pays attention to those who purchased prequalification or bidding documents as "serious" prospective bidders. They may or may not participate in the tendering, as will be described later. The paper, using the sequential-response model (e.g., [17] and [18]), examines how auctioneers and individual firms decide whether or not to proceed to the next step toward the final price bid evaluation stage. Then, the equilibrium bid function is estimated by the Heckman [19] and Lee's [20] two-step estimation method with a double selection process taken into account.

The remaining paper is organized as follows. Section II describes the traditional public procurement procedure and overviews the behavior of potential and actual bidders in our road procurement data. Section III develops the empirical methods and summarizes our used data. Section IV presents the main results and discusses some policy implications.

II. An Overview of Participation Decisions by Bidders and Auctioneers in Road Procurement

Public road projects are traditionally procured through the first-price sealed-bid competitive tenders. Through this channel, developing countries spend several percent of GDP for public roads every year. Notably, however, there are a variety of procurement systems involving different institutional elements. For instance, some auctions invite only domestic companies, while others accept international enterprises as well. But the most important difference in terms of auction design may be that some auctions adopt the strict lowest price criteria where only the price bids are compared, while others account for some "quality," which refers to anything the auctioneer cares about other than prices.[3] A typical example is prequalification. In large-scale infrastructure projects, the technical evaluation prior to comparing prices is normally required in order to ensure the quality of the purchased object or public work, the contract cost agreed, and the period designated. Without quality project outcomes, the development objective cannot be achieved. Worse, the poor quality of projects will cause an additional burden on the economy, such as high maintenance and operation costs and shorter project life.

From the auctioneer's point of view, apparently, there is a tradeoff between price and quality if the latter is costly for firms to produce and attain; the higher quality, the higher prices. In addition, if quality is also costly to prepare before the auction, the optimal number of bidders that are allowed to enter the market would decline in the presence of increased entry costs, whence limiting competition and raising the equilibrium bid. Moreover, if there are a limited number of companies that could meet highly specific qualification requirements, then the competition would also become narrow.[4] Too exclusive conditions might even be considered an indication of corruption.[5]

From the bidder perspective, they must be of necessity self-selective for a number of reasons. The fundamental reason is that potential contractors are under resource constraints to a larger or lesser extent. They may not be technologically competent enough to apply for a complex contract.[6] Even though they are potentially able to implement a project being procured, they may not temporally have available resources for new contracts because they are already devoted to other development projects elsewhere. In addition, if the entry cost is too high, bidders may decide not to enter the tendering process, though having shown interest. Finally, the bidders' strategy would also be influenced by rivals' entry and bidding behavior. In theory, it could be affected significantly if bidders are asymmetric,[7] or if bidders have private signals but do not ex ante know the true common value of the object being auctioned.[8]

Hence, bidders and auctioneers have various different reasons for not participating or not allowing them to participate in the tendering process. The sample data uncover the typical auction process for road construction and rehabilitation works, during which the number of applicants gradually shrank from

[2] In the existing endogenous entry auction literature, this difficulty tends to be avoided by relating the realized (not potential) number of bidders to explanatory variables in a Poisson or negative binomial regression model (e.g., [13]-[16]). Otherwise, one can assume that those who participated in a series of auctions at least once in the past would constitute a set of potential bidders.

[3] There are a certain amount of theoretical works on multidimensional auctions. They show that the two-stage bid evaluation system can implement the optimal mechanism maximizing auctioneer's expected profits (e.g., [21] and [22]). However, it is still far from applicable to practice.

[4] See[16] for more discussion.

[5] A crucial shortcoming of multidimensional auctions is that the award process would be less transparent and more vulnerable to corruption; authorities can easily exploit their excessive discretion (e.g., [23]-[25]).

[6] One of the solutions to this resource constraint problem is joint bidding. Bidders can overcome the possible prerequisites by pooling their financial and managerial resources with each other (e.g., [26]-[28]).

[7] Asymmetric auction theory predicts that a weaker (fringe) bidder tends to bid more aggressively in the presence of a strong (incumbent) bidder. Reference [29] shows that if a weak bidder faces a strong bidder rather than another weak bidder, he responds with a more aggressive bid distribution in the sense of stochastic dominance. The empirical evidence is supportive of this (e.g., [30]-[32]).

[8] Under the common value paradigm, competition may increase the equilibrium bid due to the winner's curse effect (e.g., [5], [33] and [34]).

13 to 4 on average (Fig. 1). At the very beginning of the process, auctioneers usually publish tender notices. About 13 companies or consortia per contract showed interest and purchased the relevant prequalification or bidding documents. If prequalification is adopted, about 10 potential bidders would apply for it. Then, about two-thirds are qualified. At this stage, only 6–7 bidders remain. About one bidder may decide not to submit a price bid for some reason, though prequalified. After the staged process involving the detailed technical evaluation prior to opening price bids, only four price bids are evaluated and compared at the final stage. In the sample, the majority of auctions adopted the two-envelope procedure, in which qualified bidders are requested to submit both price and technical bids simultaneously and the auctioneer opens price bids only if their corresponding technical bids are found substantially responsive to the bidding documents and other technical requirements. As the result, the degree of competition tends to be rather limited at the end of the auction process, pushing up public road procurement costs.

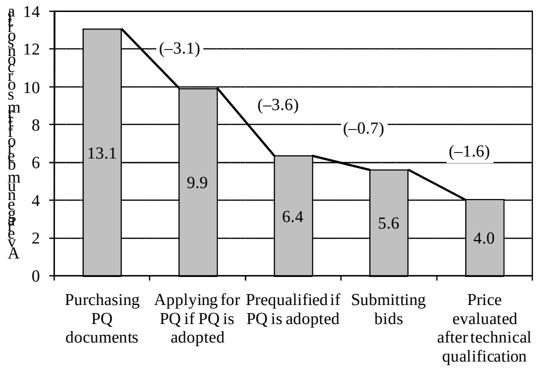

Fig. 1 Numbers of potential and actual bidders in road auctions

Because the intensity of competition changes along the bidding procedure, the relationship between the bid strategy and competition also varies depending on the stage of the selection process. Fig. 2 illustrates the competition effect when it is measured at the beginning of the tender process, i.e., the number of firms that purchased prequalification or bidding documents. Fig. 3 depicts the competition effect at the final price comparison stage. Of course, both ignore partial observability; one cannot observe bids from firms that not participated, though having showed interest. But the comparison between them indicates that Fig. 3 ignores many unrealized bids that could have been scattered where the horizontal axis is greater than seven if they were observed. It suggests that without controlling for the sample selection bias caused by this unobservability, the empirical competition effect would be biased.

III. The Empirical Models

The following sequential decisions made by an auctioneer and potential bidders are considered. Suppose that L firms purchased prequalification and/or bidding documents. These constitute a set of potential bidders, out of which M firms

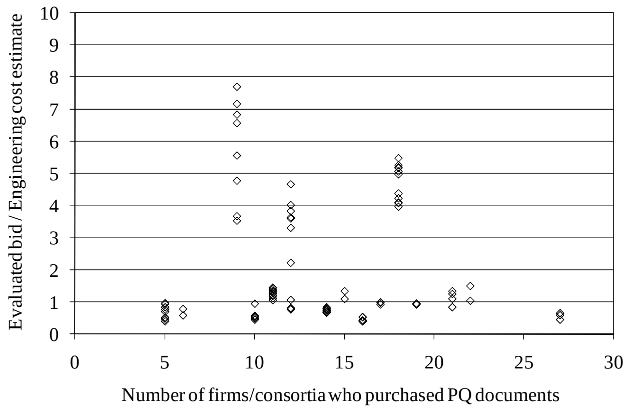

Fig. 2 Potential competition and bids

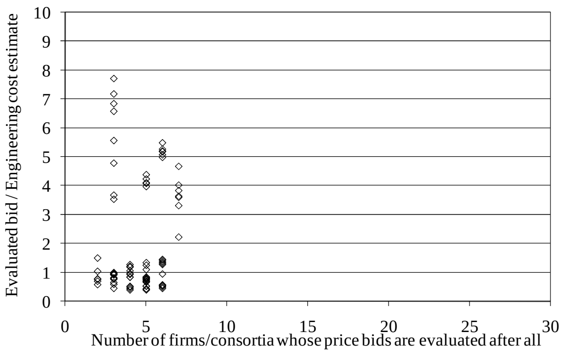

Fig. 3 Final competition and bids

applied for prequalification if the prequalification process is introduced, or just entered into the price competition if prequalification is omitted. This is the first selection made by each bidder of $\{1, \cdots, L\}$, denoted by $d1$. Then, the auctioneer qualifies only N firms from actual applicants $\{1, \cdots, M\}$ due to technical reasons. Disqualification occurs at either the prequalification or technical evaluation level. This is the second selection, denoted by $d2$. Even though qualified, bidders can still choose not to proceed to the final price comparison stage. Some qualified bidders in fact cease participating in the auction possibly because of unexpected financial and equipment constraints. But such cases are relatively rare, as shown in the previous section. Hence, the model focuses on only two major decision nodes: (i) whether firms apply for the bidding process, and (ii) whether bidders are qualified and advance to the price competition.

The selection rules are as follows:

$$d1 = \begin{cases} 1 & \text{if } \ d1^* = Z'\gamma_1 + \varepsilon_1 \geq 0 \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

$$d2 = \begin{cases} 1 | d1 = 1 \text{ if } d2^* = Z'\gamma_2 + \varepsilon_2 \geq 0 \\ 0 | d1 = 1 \text{ otherwise} \end{cases} \quad (2)$$

where $d1^*$ and $d2^*$ are latent variables but have dichotomous observable realizations, $d1$ and $d2$, respectively. Z is a vector of bidder- and auction-specific characteristics determining the selection mechanisms. The two error terms are assumed to follow a multivariate normal distribution with zero means and variances equal to unity. Potentially, the error terms can be correlated with one another. Denote this by $Cov(\varepsilon_1, \varepsilon_2) = \rho^2$. One might expect that an auctioneer disqualifies firms that have certain common unobserved characteristics, which could also systematically encourage bidders to enter into the auction. In this case, the correlation ρ will be negative.

Given the two selections, each bidder of $\{1, \cdots, N\}$ submits the following conventional symmetric equilibrium bid (e.g., [35]-[37]):

$$\ln BID = X'\beta + u \quad (3)$$

where X is composed of bidder- and auction-specific variables that influence firms' underlying cost parameters and control for heterogeneity among projects to be auctioned. BID is the evaluated bid price. This is observed only for firms that entered and were qualified. Consequently, the ordinary least squares (OLS) estimation would lead to the sample selection bias if (1) and (2) are significant ([19] and [20]).

Following the existing literature focusing on the double or generalized selection process (e.g., [38]-[41]), (3) can be consistently estimated by correcting the two selectivity biases:

$$E[\ln BID | d1 = 1, d2 = 1] = X'\beta + \sigma_{1u}\lambda_1 + \sigma_{2u}\lambda_2 \quad (4)$$

where $\sigma_{iu} = Cov(\varepsilon_i, u)$ and $\lambda_i = \phi(Z'\gamma_i)\Phi\left(\frac{Z'\gamma_j - \rho Z'\gamma_i}{\sqrt{1-\rho^2}}\right) \Big/ B(Z'\gamma_i, Z'\gamma_j, \rho)$ for $i, j = 1,2$ and $j \neq i$. ϕ is the standard normal density function and Φ is the cumulative normal distribution function. B is the bivariate standard normal distribution function.

To estimate (4), the two-step method is adopted. The first stage is estimated by a censored bivariate probit model because of partial observability, because the second selection rule $d2$ is observed only if bidders apply for the prequalification process, i.e., $d1 = 1$. The corresponding log likelihood function is:

$$L = \sum_N \{(1 - d1)\ln(1 - \Phi(Z'\gamma_1)) + d1(1 - d2)\ln B(Z'\gamma_1, -Z'\gamma_2, -\rho) + d2 \ln B(Z'\gamma_1, Z'\gamma_2, \rho)\}$$

The first term is associated with the probability that a bidder decides not to apply for the process. The second represents the case that a bidder determines to enter into the auction but does not proceed to the price comparison stage. The last expression is the probability that a bidder is qualified and its bid is evaluated after all.

Given estimated parameters, $\hat{\lambda}_1$ and $\hat{\lambda}_2$ are calculated and used for the second stage. Then, (4) can be estimated by OLS. This two-step estimator will be consistent, and the standard errors are corrected with the possible bias into account, which is mainly caused by the additional variance of λ_1 and λ_2 added to remove the selection bias. The asymptotically consistent mean square error is:

$$\sigma_u^2 | d_1 = 1, d_2 = 1 \approx \frac{1}{N}\sum_{i=1}^{N}\left(v_i - \sigma_u^2 \mu_i\right)$$

where v_i is the residual from the OLS regression of (4), and the additional error is $\sigma_u^2\mu_i = -\hat{\sigma}_{u1}{}^2 z_i'\hat{\gamma}_1\delta_{1i} - \hat{\sigma}_{u2}{}^2 z_i'\hat{\gamma}_2\delta_{2i} - [\hat{\sigma}_{u1}\delta_{1i} - \hat{\sigma}_{u2}\delta_{2i}]^2 - [2\hat{\sigma}_{u1}\hat{\sigma}_{u2} - \hat{\rho}(\hat{\sigma}_{u1}^2 + \hat{\sigma}_{u2}^2)]\frac{b(z_i'\hat{\gamma}_1, z_i'\hat{\gamma}_2, \hat{\rho})}{B(z_i'\hat{\gamma}_1, z_i'\hat{\gamma}_2, \hat{\rho})}$. $\delta_{ki} = \frac{\phi(z_i'\hat{\gamma}_k)\Phi\left((z_i'\hat{\gamma}_h - \hat{\rho}z_i'\hat{\gamma}_k)/\sqrt{1-\hat{\rho}^2}\right)}{B(z_i'\hat{\gamma}_k, z_i'\hat{\gamma}_h, \hat{\rho})}$ for $k, h = 1,2 \;\; k \neq h$.[9]

To specify the equilibrium bid function in (3), X is composed of four types of project- and bidder-specific characteristics: (i) the number of bidders participating in an auction, which is often referred to as N, (ii) project-specific observables, such as length of roads (*LENG*), number of lanes (*LANE*), engineering cost estimates (*COST*) and expected contract duration (*MONTH*), (iii) country-specific fixed effects, and (iv) observable bidder attributes. For the last, a set of dummy variables representing bidder nationalities are used to control potential heterogeneity across bidders. As one can expect, whether bidders are foreign or domestic is among the most important determinants of the bidding equilibrium strategy in large-scale development projects.

Regarding the first variable N, it must be noted that we choose the number of bidders that were qualified if prequalification was applied and stepped in the price competition stage. If prequalification is not adopted, N is simply the number of firms submitting bids. N is expected to capture the competition effect particularly in the independent private value paradigm. Notably, this is comparative statics in the conventional fixed-n approach; more competition would lead to lower procurement costs.[10] In auction theory, the

[9] See [40] for a full description.

[10] It is still theoretically possible to characterize our auctions as the common value paradigm, in which the equilibrium bid could increase with the number of bidders. However, there is little evidence supportive of this in our data, regardless of functional forms. A significant negative relationship between the

endogeneity of N is another important question for considering competitiveness (e.g., [10], [11] and [43]). At least from the empirical point of view, however, a necessary question may be whether N is common knowledge among bidders, whatever it represents. Our defined N is the best proxy in this regard. In the practical ODA procurement circumstances, serious tenderers are likely to share a good sense of how many rivals are remaining for the final price competition, either through the formal prequalification result publication and informal business relationship. Therefore, the number of bidders that were prequalified and submitted price bids is considered the best information of N known by tenderers.[11]

Following the existing literature (e.g., [35], [43] and [44]), two instruments are used for a vector of selection determinants, Z.[12] One measure is the total amount of contracts—in our sample—awarded to each firm in the three-year period before a particular contract is auctioned (*BKLG*). If a bidder forms a joint venture, the average backlog among consortium members is used. Another variable to complement this is the amount of total transport ODA disbursed to each country in the three-year period prior to the auction (*CAID*).[13] The basic idea behind these variables is that if prospective firms are already devoted to other development projects elsewhere, fewer bidders would be willing to bid on further new works because they might be too busy. An implicit assumption is that firms are resource-constrained, which will in fact be verified in the following analysis.

Table I shows the summary statistics. Our sample covers about 325 potential bidders that are interested in one of the 31 road procurement auctions under 11 projects in nine developing countries.[14] 70 percent of them applied for the tendering process. 184 firms are identified as those who were technically evaluated, and about 64 percent passed the technical examination. There were 117 bidders that were technically qualified, but not all of them participated in the price competition; only 84 percent did. Therefore, we observe 98 winning and losing bids, of which the average is about 23 million U.S. dollars. Note that both winning and losing bids are equally informative to estimate the equilibrium bid function, because the auction format normally used for infrastructure project procurement is the standard first-price sealed-bid auction.

TABLE I
SUMMARY STATISTICS

Abbr.	Variable	Obs	Mean	Std. Dev.	Min	Max
BID	Evaluated bid [1]	98	22.70	23.90	0.37	115
d1	Dummy for applicants to the process	325	0.70	0.46	0	1
d2a	Dummy for the technically qualified	184	0.64	0.48	0	1
d2b	Dummy for bidders of which bids are compared	117	0.84	0.37	0	1
N	Number of bidders proceeding to the price bidding stage	325	5.74	1.92	2	11
LENG	Length of roads (km)	325	39.59	50.50	0.90	278
LANE	Number of lanes	325	2.95	1.29	2.00	6
COST	Engineering cost estimate [1]	325	33.12	48.83	0.39	176
MONTH	Estimated contract duration (months)	325	31.12	13.81	9.00	45
BKLG	Firm's backlog in the past three years [1]	325	7.78	24.40	0.00	189
CAID	Total transport aid received by the project country [1]	325	410.89	318.82	5.73	1,001

[1]In millions of constant 2004 U.S. dollars.

The contracts differ considerably in financial and technical terms. While lower bids are less than 0.4 million U.S. dollars, high bids may exceed 100 million U.S. dollars. The average length of roads is about 40 km, but it ranges from 1 km to 280 km. The number of lanes also varies from two to six. The average project duration is estimated at 31 months. The average of total contract amounts obtained by a firm in the three-year period prior to the auction is about 8 million U.S. dollars. But again, there is huge variation; some firms were awarded several similar projects in recent years, and others not. In addition, each recipient country seems to receive a considerable amount of aid in the transport sector alone. Note that the last is a country-specific but time-variant variable.

IV. Estimation Results and Implications

Before presenting the equilibrium bid equation estimated by the two-step double selection technique, the sequential response model is performed to examine how prospective firms determine to participate in each step of the auction and how the auctioneer rejects some of the applicants. For this, the second decision $d2$ is separated further into two stages. First, the auctioneer can determine to technically qualify each applicant prior to the price comparison; this process is denoted by $d2_a$. Then, qualified bidders can decide whether to proceed to the price comparison. This is denoted by $d2_b$. It must be noted that

bids and the number of bidders was found even in a partially nonparametric specification [3]. In the current paper, the competition effect is specified in logarithmic form, because it is known that the mapping between winning bids and the number of bidders is never linear[42]) and the logarithmic models often better fit actual auction data (e.g., [6], [35] and [36]).

[11] Technically, our N is different from the sum of $d2_a$ and the sum of $d2_b$ as well. It represents the number of prequalified bidders bud may include those who are disqualified technically in the pre-stage of price bid evaluation. This is the case where the two-envelope procedure is adopted. In this system, all potential bidders are requested to submit both price and technical proposal and an auctioneer opens the price bids only if the submitted technical proposal meets the required standards. It will play the similar role as prequalification, but the order is difference and the scope of the examination may be more technical (see [16] for more discussion on this).

[12] X is also part of Z except for N, because at the preselection stage, participants may not be sure how many firms would finally decide to apply for it.

[13] Our sample merely represents several percent of total ODA allocated to the transport sector all over the developing world. Therefore, *CAID* is expected to capture the broader market conditions than *BKLG*. The used aid data come from the OECD Creditor Reporting System database.

[14] Our sample originally covers about 450 potential bidders but is reduced to 325 due to missing relevant data.

TABLE II
BINARY RESPONSE MODEL FOR BIDDERS' PARTICIPATION

	$d1$	$d1$	$d2_a$	$d2_a$	$d2_b$	$d2_b$
ln *LENG*	-0.05	-0.37**	-0.25**	-0.56**	-0.85***	-0.71***
	(0.09)	(0.15)	(0.11)	(0.29)	(0.32)	(0.27)
ln *LANE*	-1.02**	-0.19	-0.50	-1.61**	-1.63*	-1.91**
	(0.40)	(0.54)	(0.45)	(0.79)	(0.90)	(0.85)
ln *COST*	-0.07	-0.32**	-0.19*	-0.19	-0.11	-0.33
	(0.11)	(0.13)	(0.12)	(0.15)	(0.19)	(0.30)
ln *MONTH*	-0.31	1.32***	0.16	0.85	-1.45	3.22
	(0.30)	(0.46)	(0.36)	(0.76)	(1.12)	(3.68)
ln *BKLG*			0.03***	0.02**	0.01	0.01
			(0.01)	(0.01)	(0.01)	(0.01)
ln *CAID*	-0.09	0.06	-0.10	0.005	-0.78**	-3.14*
	(0.08)	(0.14)	(0.10)	(0.506)	(0.32)	(1.67)
Constant	3.11***	-0.29	2.22**	3.12*	15.51***	13.67***
	(0.843)	(1.28)	(1.03)	(1.85)	(4.68)	(4.30)
Obs.	252	252	184	184	117	117
Wald-chi2	68.23	145.38	27.48	57.98	21.46	42.03
No. of country dummies	0	3	0	4	0	2
No. of bidder nationality dummies	0	0	0	7	0	5
Chi2 test statistics:						
H_0: Coef. of country and bidder nationality dummies=0		61.89***		43.24***		8.38

The dependent variable is the bidder's entry selection at each stage. The robust standard errors are shown in parentheses. *, ** and *** indicate the 10%, 5% and 1% significance levels, respectively.

$d2_a$ is the decision making by the auctioneer, while $d2_b$ as well as $d1$ are primarily determined by bidders. Assuming the normal distribution, the probabilities can be written as:

$$\begin{aligned} &\Pr(d1=0)=\Phi(Z'\gamma_1) \\ &\Pr(d1=1, d2_a=0)=[1-\Phi(Z'\gamma_1)]\Phi(Z'\gamma_{2a}) \\ &\Pr(d1=1, d2_a=1, d2_b=1)=[1-\Phi(Z'\gamma_1)]\cdot \\ &\qquad\qquad [1-\Phi(Z'\gamma_{2a})]\Phi(Z'\gamma_{2b}) \end{aligned} \tag{5}$$

Since these are sequential decisions, the parameters can be estimated by performing the probit model with only relevant subsample in each case ([17] and [18]). An important assumption for these estimators is obviously that the random factors influencing responses at individual stages are independent.

In the sample data, 325 firms constitute a set of potential bidders,[15] out of which 228 decided to apply for the selection process. Then, prior to the following price competition, at least 117 and 67 bidders were technically qualified and disqualified, respectively.[16] Out of the qualified bidders, 98 firms actually decided to bid on the final financial stage and thus 98 price bids are observable in the data.

[15] Only 252 observations are used for the first probit model, because one of the explanatory variables takes the same value for 73 cases. These are perfectly predicted in our specification.

[16] 44 observations are not used for the second probit model, because the prequalification results are unavailable in these cases.

Table II presents the probit results.[17] There is a noticeable contrast between the auctioneer's and bidders' behavior with regard to auction participation. Bidders are more likely to enter in the tendering when their potential backlogs, which are measured by either *BKLG* or *CAID*, can be considered relatively moderate. This is consistent with the previous literature. It implies that bidders have certain capacity constraints. On the other hand, auctioneers would be more likely to qualify bidders that have more backlogs. This must reflect the tendency toward more experienced and reputable contractors. This is not surprising, because the prequalification process normally requires prospective bidders to have experienced similar development projects in the past. And intuitively, auctioneers may normally be comfortable contracting with incumbents. The quality of public works cannot be compromised from the government point of view.

However, these results highlight an important challenge for governments to procure infrastructure projects: Potential contractors are resource-constrained, but auctioneers may prefer to contract with those who have undertaken many other development projects. As the result, the market competition at the final stage will tend to be limited. But then the expected contract amount will increase due to lack of competition among contenders, and market concentration may also be of potential concern.

Other than the backlog variables, it is found that larger road projects would attract fewer bidders. It is because firms that can undertake large-scale projects are limited due to their inevitable resource boundaries; the coefficients of *LENG*, *LANE* and *COST* are broadly negative and significant for the bidder's entry decisions $d1$ and $d2_b$. It is also because auctioneers have a propensity to put more emphasis on bidders' technical capacity and past experience particularly when contracting out a large project. Thus, the probability that an auctioneer disqualifies an applicant would increase with the size of contract holding everything else constant. In the model for $d2_a$, again, *LENG*, *LANE* and *COST* have negative coefficients.

Turning back to the formal selection model to be analyzed, two main decision nodes are focused on: $d1$ and $d2$. $d2_a$ and $d2_b$ can be considered to have been merged. Notably, however, $d2$ mainly represents the former decision by the auctioneer ($d2_a$), because the number of bidders that were qualified but did not participate in the price competition is much small in the sample. It is also noteworthy that when estimating a censored bivariate probit model for $d1$ and $d2$ as the first stage regression, the two error terms can be correlated with one another unlike the above sequential response model. Table III shows the results, which are broadly consistent with the sequential response models estimated above; potential bidders are faced with resource constraints and often decide not to enter new tender when the contract amount is large. The coefficient of ln*COST* is negative, and the coefficient of ln*CAID* is also negative in the second

[17] Note that many country- and nationality-specific fixed effects are omitted because there are many cases where the fitted probability that one of the country or bidder nationality dummy variables equals unity is exactly either one or zero.

TABLE III
CENSORED BIVARIATE PROBIT MODEL FOR BIDDERS' ENTRY AND AUCTIONEER'S REJECTION

	Coef.	Std.Err.	Coef.	Std.Err.
Equation *d1*				
ln *LENG*	–0.039	(0.092)	0.823	(1.085)
ln *LANE*	–0.886	(0.427)**	6.679	(2.950)**
ln *COST*	–0.145	(0.128)	–5.741	(1.815)***
ln *MONTH*	0.026	(0.312)	27.871	(10.268)***
ln *BKLG*	0.176	(0.005)***	0.010	(0.012)
ln *CAID*	–0.084	(0.084)	–26.505	(10.843)**
Constant	4.805	(0.876)***	40.519	(19.833)**
Equation *d2*				
ln *LENG*	–0.125	(0.106)	–0.782	(0.256)***
ln *LANE*	0.296	(0.464)	–1.169	(0.669)*
ln *COST*	–0.188	(0.126)	–0.041	(0.133)
ln *MONTH*	–0.250	(0.339)	0.001	(0.601)
ln *BKLG*	0.015	(0.014)	0.018	(0.008)**
ln *CAID*	0.074	(0.088)	1.275	(0.333)***
Constant	1.140	(1.054)	0.060	(1.773)
ρ	–0.310	(0.476)	–0.109	(0.374)
Obs.	285		285	
Wald-chi2	1482.66***		1390.33***	
No. of country dummies	0		4	
No. of bidder nationality dummies	0		5	
Chi2 test statistics:				
H_0: Coef. of country and bidder nationality dummies=0			315.36***	

The dependent variables are the bidder's entry decisions at individual stages. The robust standard errors are shown in parentheses. *, ** and *** indicate the 10%, 5% and 1% significance levels, respectively.

column model. [18] On the other hand, auctioneers would consistently prefer to preselect enterprises that have more past experiences, even though they may not be available due to their resource commitment to something else.

The correlation between the two binary responses seems subtle. It is negative but insignificant. In the following analysis, the second column model is used for inferring λ_1 and λ_2 for (4), because the country and nationality fixed effects are found unignorable; the chi square test statistic is estimated at 315.36. If this is the case, it means that there are some unobservables that would facilitate bidders' entry but discourage auctioneers from qualifying them. Some characteristics shared by new growing companies may be one possibility. While new entrants are eager to enter the market, they may not be trustworthy enough given their past experiences.

Finally, the consistent equilibrium bid function is presented in Table IV. The first column model is the simple OLS estimation, which may not be consistent because of uncontrolled selectivity bias. As usually expected, nonetheless, the competition effect is negative, meaning that the equilibrium bid, whence the government procurement cost would decrease with the number of participating bidders.[19] It is also reasonable that the submitted bids would be higher for more valuable contracts, longer highways, and wider roads.

When correcting the possible double selection bias, it is found that the competition effect is still statistically significant but slightly larger (in absolute terms) at –0.707.[20] It means that unrealized would be pro-competitive if they were observable. This can be interpreted as the potential benefits of unrealized competition. The other explanatory variables have the similar coefficients to the OLS regression.

TABLE IV
TWO-STEP ESTIMATION FOR EQUILIBRIUM BID STRATEGY WITH DOUBLE SELECTION PROCESS

	OLS	Double selection model
ln *NUM*	–0.687**	–0.707*
	(0.318)	(0.368)
ln *LENG*	0.368***	0.447***
	(0.093)	(0.159)
ln *LANE*	1.517***	1.621***
	(0.275)	(0.393)
ln *COST*	0.240***	0.226**
	(0.088)	(0.110)
ln *MONTH*	–0.075	–0.108
	(0.504)	(0.580)
λ_1		0.341
		(0.274)
λ_2		–0.314
		(0.388)
Constant	15.054***	15.283***
	(1.916)	(2.206)
Obs.	98	98
R-squared	0.939	0.940
F-statistics	62.77***	56.97***
No. of country dummies	6	6
No. of bidder nationality dummies	8	8
F test statistics:		
H_0: Coef. of country and bidder nationality dummies=0	11.85***	9.41***

The dependent variable is the bidder's entry selection at each stage. The standard errors are shown in parentheses. *, ** and *** indicate the 10%, 5% and 1% significance levels, respectively.

The hypothesis that the difference in coefficients between the two models is not systematic cannot be rejected by the standard chi-square test. The test statistic is 2.11 and well below the conventional critical values. Therefore, it can be concluded as follows: There are many prospective bidders, of which bids are not observed, and various factors would likely influence bidders' entry decision and auctioneer's qualification decision. Nonetheless, the equilibrium bid function may be able to be estimated effectively through the OLS regression with only observed bids. The competition effect may be slightly underestimated, but the bias will be small.

[18] All four measures of project heterogeneity are related to the scale or size of the work. Unsurprisingly, therefore, the estimated coefficients of these variables may be sensitive to specifications. One of the most important independent variables controlling for project heterogeneity may be engineering cost estimates. If the other three variables are omitted from the models, it can be found that the coefficient of the project value is always negative for both equations. The larger a project, the fewer contractors there are who could apply for it. And the larger a project, the fewer applicants there are who are prequalified.

[19] For more discussion on this static competition effect, see [3].

[20] Note that the standard errors were corrected by accommodating the additional disturbance caused by the two bias correction terms; but the coefficient still remains significant.

The estimated bid function reveals another important challenge in procuring infrastructure projects, which is the tradeoff between competition and economies of scale. The bid function exhibits economies of scale; for instance, naturally, longer roads will cost more, because more inputs are required; but the unit cost would decrease with the length of roads in a package. The coefficients are well below one (i.e., 0.368 in the OLS case and 0.447 in the double selection model), meaning that a 1-percent increase in road length would raise the equilibrium bid by only about 0.4–0.5 percent, holding everything else constant. Therefore, governments could save public spending, if they design relatively large procurement packages. However, it will contradict the competition objective; as shown above, a smaller number of applicants could be qualified for longer road projects, and highly valuable contracts could also attract a few bidders.

To highlight the above dilemma between competitiveness and economies of scale, a comparative static analysis is considered. The baseline scenario is evaluated at sample means for explanatory variables. Suppose that the auctioneer downscales the size of contract by 10 percent in terms of engineering cost estimate, leaving everything else unchanged.[21] Then, the probability that a prospective firm decides to apply for the process would increase from 0.69 to 0.74 (Table V). This is because more enterprises would be able to accommodate smaller works. The probability of an applicant being qualified would also increase 0.34 to 0.36, because the auctioneer might be less likely to disqualify bidders for smaller projects. If the predicted probabilities are simply translated into the competitiveness variable, *N*, the degree of competition would increase by 5.2 percent, which would result in lowering bids by 3.7 percent according to the estimated bid function. This is the benefit from the intensified competition. At the same time, a 10-percent reduction in engineering cost estimate will reduce the bids by 2.3 percent, because of the direct effect of changing the specification of the project. However, recall that the cost estimate was reduced by 10 percent in the scenario. Despite that, the auctioneer can expect only a 6-percent reduction in predicted bids. As in this scenario, hence, the simple unbundling approach, which aims at dividing a project to a number of small packages and promoting more local bidders, may not always be the solution to contain government spending.

The policy implication is straightforward but challenging. Essentially as long as potential bidders are resource-constrained, the market competition must of necessity become limited throughout the selection process. If auctioneers divide a project into several small contracts in order to loosen bidders' resource constraints, competition can be enhanced somewhat, but the benefit from economies of scale would be sacrificed. These contradictory difficulties could not be solved unless more skilled and competent contractors would emerge and enter in the public procurement markets. In this regard, new entry and local business development, though not achievable in the short term, are of particular importance for sustainable fiscal positions and stable economic development.

[21] Apparently, it is more natural that some attributes of the project would be changed if the engineering cost is changed. For simplicity, however, the analysis focuses on a simple shock in one single variable.

TABLE V
A SCENARIO ANALYSIS

	Baseline	Scenario: 10% reduction in engineering cost estimates
Avg. predicted probability ($d1$=1)	68.8	74.1
Avg. predicted probability ($d2$=1 given $d1$=1)	34.4	36.2
Predicted bid changes associated with *N*		-3.7
Predicted bid changes associated with *COST*		-2.3

Although it is beyond the scope of this paper, the above discussion may provoke governments to use an alternative approach to procure public contracts, i.e., through negotiation. Theoretically, [8] shows that more complex transactions would be likely to be plagued by ex post adaptations and may be able to be better accommodated by a cost-plus contract, which is opposite to a fixed price contract typically assumed in the auction-based public procurement. Reference [43] also provides the supportive evidence of this in the private sector building construction industry. Obviously, however, some important advantages of auctions may have to be ignored, e.g., transparency, public accountability, nondiscrimination, and other corruption prevention effects, in addition to competitiveness. These factors may be unignorable in particular in the context of public procurement.

V. CONCLUSION

Limited competition is one of the major concerns in public infrastructure procurement. The degree of competition that one can observe at the very end of the auction process tends to be limited perhaps to about 4–5 bidders. Although one can still expect the conventional competition effect in a static sense, it is important to recall that the entry decision by prospective bidders is potentially endogenous. There are a number of hidden bidders, who are interested but may decide not to be involved into the selection process. Hence, the observed distribution of bids can be much different from the distribution of bids that would have been submitted if those potential bidders have participated.

Because of this partial observability, the paper applied the double selection model to procurement data from public road projects in developing countries and examined why some companies did not participate or were not allowed to participate in the bidding process. The estimation results highlight several challenges in infrastructure procurement. Bidders are resource-constrained and self-selective. A few companies can apply for larger road projects. At the same time, auctioneers also tend to limit participation as the contract size increases. They prefer to contract with only experienced contractors. This is the reason the market competition ends up being rather restricted, pushing up public infrastructure procurement costs.

The estimated equilibrium bid strategy also suggests possible economies of scale; government procurement costs could be contained by increasing the size of contracts. But it would risk jeopardizing the expected competition effect because, again, larger projects could attract fewer bidders.

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