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# BIDDERS' ENTRY AND AUCTIONEER'S REJECTION: APPLYING A DOUBLE SELECTION MODEL TO ROAD PROCUREMENT AUCTIONS

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Public procurement is a dynamic process involving vendors, contractors and procuring agencies. Even before submitting bids, competition among contractors may already have started. Given the nature of public work and expected strategies of rivals, some firms decide to enter the market, but others do not. Procurers can also enhance or limit the bidder participation through various ex ante qualification procedures for quality assurance purposes. Some applicants are qualified, but others are not. Thus, the selection process has two dimensions: bidders self-select, and an auctioneer may (dis)qualify some applicants. The paper explores this selection dynamics, using procurement data from road projects in developing countries. It shows that bidders are selecting themselves; low-cost firms are more prone to enter the market. But they are more likely to be rejected for technical reasons. Procurement design, such as contract size, and public governance are also found important determinants of the entry strategy of firms.

*JEL classification codes*: H54, D44, C35
*Key words*: auction theory, endogenous bidder entry, infrastructure development, public procurement.

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## I. Introduction

Public procurement is an important policy issue for governments. This is because public spending usually accounts for a significant portion of the economy, and the vast majority of it goes through the public procurement systems (OECD 2005). However, designing an efficient public procurement mechanism is still challenging in particular for developing countries, because the selection process is highly complicated and dynamic, involving a number of stakeholders, such as venders, suppliers and procuring agencies. They are explicitly and implicitly interacting with each other.

Infrastructure procurement has long been faced with significant difficulties, such as limited competition (e.g., Foster 2005; NAO 2007) and alleged corruption and collusion (e.g., Gupta, 2001, 2002; Olken, 2007). Indeed, infrastructure development projects are often very expensive, complex and resource-intensive. On one hand, therefore, high technical requirements may limit contractor participation in competitive bidding, possibly leading to corruption and tacit collusion. On the other hand, the quality of large infrastructure projects should not be compromised from the government's point of view, since the economic and financial costs of the project's failure would be enormous. As the result, an inherent tradeoff emerges between price and quality in infrastructure procurement.

The current paper casts light on this dynamics in public procurement, using data from road projects in developing countries. Traditional auction theory assumes that the number of bidders is fixed (i.e., fixed-*n* approach) and argues that increased competition would lower procurement costs. However, the bidders' participation decision appears to be more dynamic and endogenous. Potential contractors decide whether to enter the tendering, depending on their endowments, rivals' behavior and the nature of projects being auctioned. Some enter the market, and others do not. Thus, competition must be characterized by not only submitted prices but also the whole process of potential bidders' entry decisions. The World Bank Procurement Guidelines clearly stipulate that lack of competition at the time of price submission is *not* determined solely on the basis of the number of bidders, because the procurement process can be competitive if the bid is satisfactorily advertised and prices are reasonable in comparison to market values.[1]

Auctioneers –namely governments or executing agencies of development projects– may also have incentives to qualify or disqualify applying contractors. In general, they would like to promote bidder participation in competitive bidding. The reason

[1] See the World Bank Guidelines Procurement under IBRD Loans and IDA Credits, Clause 2.61.

is that the procurement costs are expected to approach the lowest possible market prices, as the number of bidders increases. This is especially true under the independent private value paradigm,[2] and a number of empirical auction papers are supportive of this (e.g., Brannman et al. 1987; Gupta 2002; Iimi 2006). But auctioneers would prefer to limit competition for different reasons. They may want to exclude from the selection process those who would likely fail to fulfill a public contract being awarded. Especially in infrastructure procurement, project owners try to avoid taking any risk that the public infrastructure will not be delivered with the specified quality within the agreed contract period.

The economic and financial costs of awarding to incompetent contractors are enormous. Projects could be delayed, as in many large-scale infrastructure projects (Flyvbjerg 2005; Alexeeva et al. 2008). People would not benefit from planned infrastructure services during the delays. Delays would also push up project costs. The average cost escalation during the project implementation period is estimated at 27.6 percent in infrastructure projects (Flyvbjerg et al. 2002). The massive cost overruns and project delays would undermine efficiency and predictability of the government budget. This has been a chronic problem in many developing countries, causing significant implicit and explicit economic losses, such as misprioritization of public resources.[3]

It is an uneasy question how to invite good contractors to public tendering and select the best one, because the selection process is endogenous and multidimensional. Auction theory with endogenous bidder entry predicts that bidders will enter until their expected profits are driven down to the entry cost (e.g., McAfee and McMillan 1987; Levin and Smith 1994). In practice, however, the mechanism appears more complicated than theory. Bidders always self-select throughout the process, taking

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[2] The determination of the paradigm must of necessity defer to individual empirical works (e.g., Bajari and Hortacsu, 2003). The official development assistance (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 (Bajari and Tadelis, 2001). Also those private factors remain different even after the contract is awarded. By contrast, political instability and regulatory credibility are considered as a common uncertainty 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.

[3] See Estache and Iimi (2008) for further discussion.

into account the cost of participating in the competition and the probability of winning a contract. Auctioneers can also screen bidders at different levels. Empirically, this raises not only a traditional endogeneity problem associated with the number of bidders (e.g., De Silva et al. 2003; Li and Perrigne 2003; Ohashi 2009) but also a partial observability issue; the econometrician can observe bids only if firms decide to participate in the competitive bidding and if they are qualified through all the prequalification procedures.[4] Notably, bidders can withdraw their participation even though qualified. This particular case may raise concern about collusion. In fact, governance is often expected to be an important determinant of the public procurement performance.

The current paper collects data on potential contractors of public road projects in developing countries. In general, it is not easy to identify potential bidders, simply because they are not observable. The paper pays attention to those who purchased prequalification and bidding documents. They may or may not participate in the tendering but can be considered as a maximum set of potential bidders. Then, the paper applies the Heckman (1979) and Lee (1978) two-step estimation method with a double selection process to estimate the equilibrium bid function. The remaining paper is organized as follows. Section II overviews the common practices of public road procurement in developing countries. Section III develops our empirical method and discusses econometric and data issues. Section IV presents the main results and argues some policy implications. Section V examines the robustness of our estimates, using the sequential response model and a partially nonlinear regression technique. Then Section VI concludes.

## II. An overview of public road procurement in developing countries

The public road procurement markets are significant in many countries. In particular in developing countries, several percentage points of GDP are spent on public road development and maintenance (e.g., Briceno-Garmendia et al. 2008). However, financial resources required are often not sufficient. 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. Along with further revenue mobilization and expenditure prioritization, efficiency in public procurement is one

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[4] Whether or not to open price bids submitted by disqualifiers is dependent on the underlying procurement system. See the following section for further details.

of the important aspects to enhance fiscal space (e.g., IMF 2005; World Bank 2005). In recent years, some countries, such as Albania, Brazil, Ghana and India, have embarked upon substantive public procurement reforms, mainly focusing on publishing more information and increasing transparency in the selection processes.

Open and nondiscriminatory competition with free entry is a main principle in public procurement systems. This is also expected to contribute to minimizing the risk of collusion and corruption. Public roads are typically procured through the first-price sealed-bid competitive bidding. Official development assistance (ODA) projects, from which the current paper collects data, follow the same principle in general. But there is a wide variation in detailed selection procedures.[5] For instance, domestic content requirements have long been argued; some auctions invite only domestic companies, while others accept international competitors. The most important difference in public procurement design may be whether to account for "quality," which refers to anything the auctioneer cares about other than prices. Some auctions strictly follow the lowest-price criteria where only prices are taken into account. But others take "quality" into consideration.[6] Road works are relatively simpler than other infrastructure projects. Still, whether to include the quality-based evaluation procedure could significantly affect bidders' entry and bidding behavior. In large-scale infrastructure projects, ex ante technical evaluations are usually adopted. This is because the quality of the projects is of particular concern for governments. Accordingly, auctioneers will be faced with an important tradeoff between price and quality: The higher the quality, the higher the prices. Quality is normally costly to produce. In addition, if higher technical standards raise the barrier to entry, this would also add to procurement costs.[7]

The quality-based selection makes potential bidders self-selective, because they are usually under certain resource constraints. Firms may or may not possess sufficient skills and technology to meet the requirements for a project.[8] Even though firms

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[5] The following discussion mainly focuses on public infrastructure projects financed by international financial institutions, such as the World Bank. The individual country's domestic procurement systems may differ from the international practices. But the main principles are not significantly different.

[6] 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., Che 1993). However, it is still far from applicable to practice.

[7] See Estache and Iimi (2009) for more discussion.

[8] One of the solutions to the resource constraint problem is joint bidding. Bidders can pool their financial and managerial resources with each other to overcome difficult prerequisites (e.g., Hendricks and Porter 1992; Iimi 2004).

can potentially meet the requirements, the financial and human resources may be temporally unavailable because of their other jobs elsewhere. Thus, large market players can relatively easily meet the technical requirements, but new fringe bidders are often disqualified because of lack of the past experience.[9] Conversely, if requirements are too low, excess competition may occur. Many low-cost contractors would be willing to enter the market with very competitive bids. This could result in aggravating the winner's curse problem, which is a typical phenomenon when bidders have private signals but do not ex ante know the true common value of the object (e.g., Klemperer 1998).[10] Importantly, if contractors are allowed to declare default and undergo renegotiation after the contract award, auctioneers may have to be concerned about unrealistically low bids submitted by unskilled contractors, often referred to as the "low balling" strategy (Ware et al. 2007).

In the ODA-financed infrastructure projects, two screening procedures are common: prequalification and ex ante technical evaluation. Prequalification examines whether applicants meet basic financial, technical and experiential criteria to carry out the public work being contracted out. The two-envelope procedure examines bidders' technical responsiveness in more details. Potential bidders are requested to submit both price and technical proposals, and an auctioneer opens the price bids only if the submitted technical proposals meet the required standards. In practice, ex post evaluation may be applicable. But there would be no difference in theory. Under the post evaluation system, price bids are not accounted for anyway, if technical bids are found irresponsive to the bidding documents. In our sample data, most of the auctions adopted the prequalification process. More than half of the auctions relied on the two-envelope procedure.

Firms can withdraw their participation anytime throughout these qualification procedures. They may decide not to apply for the prequalification because of expected intense competition or because of their resource constraints. Firms can also choose to withdraw their bids even if prequalified. From the anti-collusion point of view, this may be a matter of particular concern, because there seems to be no sufficient

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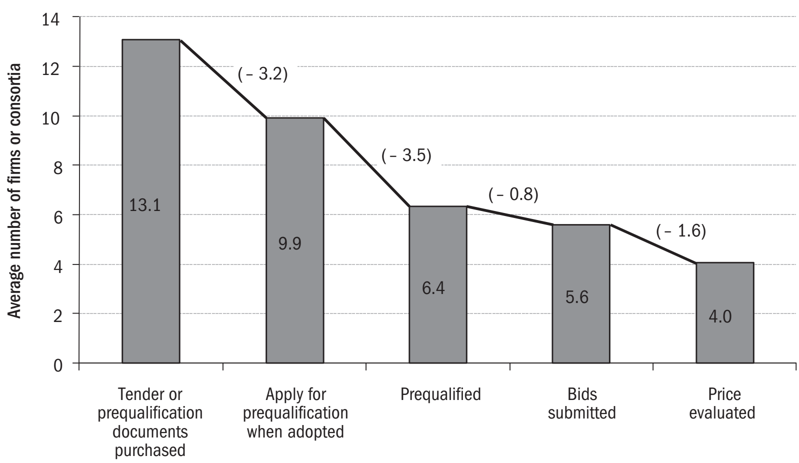
[9] Auction theory analyzes the asymmetry among bidders. But it remains static; it is predicted that a weaker (fringe) bidder tends to bid more aggressively in the presence of a strong (incumbent) bidder. Maskin and Riley (2000) shows that if a weak bidder faces a strong bidder rather than another weak bidder, he responds with a more aggressive bid distribution in the sense of stochastic dominance. The empirical evidence is supportive of this (e.g., De Silva et al. 2002, 2003; Estache and Iimi 2010).

[10] Under the common value paradigm, competition may increase the equilibrium bid due to the winner's curse effect (e.g., Milgrom and Weber 1982; Klemperer 2002).

reason for qualifiers to withdraw their bids just before the time of price submission (e.g., Klemperer 2002; Haggarty et al. 2002).

Figure 1 illustrates the actual dynamics observed in public road procurement auctions in developing countries. The number of applicants gradually shrank from 13 to 4. At the beginning of the process, auctioneers usually publish tender notices. About 13 companies or consortia showed interest and purchased the 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, even though prequalified. After the staged process involving the detailed technical evaluation prior to opening price bids, only four price bids are compared after all. As the result, more than two-thirds of potential price bids are not observable, either because firms were disqualified or because they withdrew their bids spontaneously. This partial observability is clearly an issue from an econometric perspective.

**Figure 1. Numbers of potential and actual bidders in road auctions**




## III. The empirical models

The following sequential decisions are considered: Suppose that $L$ firms are initially interested in a road project and purchase the prequalification and/or bidding documents. These firms constitute a set of potential bidders, out of which $M$ firms apply for the prequalification process. If prequalification is not adopted, all $L$ firms are simply assumed to proceed with the next stage. This is the first selection made by each bidder of $\{1,\ldots,L\}$, denoted by $d1$. Then, an auctioneer qualifies only $N$ firms from applicants $\{1,\ldots,M\}$ according to certain technical criteria. 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 bidding stage. However, such cases are relatively rare, as shown in Figure 1. Hence, the model focuses on only two decision nodes: (i) whether firms apply for the bidding process, and (ii) whether bidders are qualified to participate in the price competition.

The selection rules are specified as follows:

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

and

$$d2 = \begin{cases} 1 & \text{if } d1 = 1 \text{ and } d2^* = Z'\gamma_2 + \varepsilon_2 \geq 0 \\ 0 & \text{if } d1 = 1 \text{ and } d2^* = Z'\gamma_2 + \varepsilon_2 < 0, \end{cases} \tag{2}$$

where $d1^*$ and $d2^*$ are latent variables and have dichotomous observable realizations, $d1$ and $d2$, respectively. $Z$ is a vector of bidder- and auction-specific characteristics determining the selection decisions. The two error terms are assumed to follow a multivariate normal distribution with zero means and variances equal to unity. The error terms are potentially correlated with one another. Denote this by $\mathrm{Cov}(\varepsilon_1,\varepsilon_2) = \rho^2$. One may expect that firms disqualified by an auctioneer might share certain common characteristics. For instance, inexperienced firms are less likely to be qualified, because auctioneers may not prefer to contract out public work to those companies due to quality concerns. But at the same time, these inexperienced firms may be more likely to enter the market, because their underlying costs are presumably low. In this case, the correlation $\rho$ would be negative.

Given that $d1 = 1$ and $d2 = 1$, suppose that each of $\{1,\ldots,N\}$ submits a bid. The following conventional symmetric equilibrium bid function is assumed (e.g., Porter and Zona 1993; Gupta 2001; Iimi 2006):

$$\ln BID = X'\beta + u \tag{3}$$

where $X$ is composed of bidder- and auction-specific variables, which aim to control for heterogeneity across bidders and among projects. $BID$ is the evaluated bid price.

This is observable for only those who entered and were qualified. Accordingly, the ordinary least squares (OLS) estimation would be biased by sample selection, if the error in equation (3) is correlated with the error term in equations (1) or (2) (Heckman 1979; Lee 1978).

The double selection technique is used to remove the two potential selectivity biases from Equation (3) (e.g., Poirier 1980; Lee 1983; Tunali 1983; Mohanty 2001):

$$E\left[\ln BID \mid d1=1, d2=1\right] = X'\beta + \sigma_{1u}\lambda_1 + \sigma_{2u}\lambda_2 \tag{4}$$

where $\sigma_{iu} = \mathrm{Cov}(\varepsilon_i, u)$ 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 $j \neq i$. $\phi$ is the standard normal density function and $\Phi$ is the cumulative normal distribution function. $B$ is the bivariate standard normal distribution function. Note that the residual term $u$ in Equation (3) is normally interpreted as an unobservable cost parameter of individual firms. Therefore, the coefficient of $\lambda_1$ is expected to be negative, because low-cost contractors would be more likely to enter the procurement market with competitive prices. By contrast, the coefficient of $\lambda_2$ would likely be positive, because auctioneers tend to qualify only experienced contractors. But their costs are also likely to be high. Thus, their bids would be systematically high. This means that $\sigma_{2u} > 0$.

To estimate equation (4), the two-step method is used. The first stage is estimated by a censored bivariate probit model because of partial observability. 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:

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

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 the estimated parameters $\hat{\gamma}_1, \hat{\gamma}_2$ and $\hat{\rho}$, the inverse Mill's ratios, $\hat{\lambda}_1$ and $\hat{\lambda}_2$, are calculated and used for the second stage. Then, Equation (4) can be estimated by OLS. This two-step estimator will be unbiased, but the standard errors still need to be corrected because of the bias caused by the additional variance of $\lambda_1$ and $\lambda_2$. The asymptotically consistent mean square error conditional on the two selection results is:

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

where $v_i$ is the residual from the OLS regression of Equation (4), and the additional error is $\sigma_u^2 \mu_i = -\hat{\sigma}_{u1}{}^2 z_i'\hat{\gamma}_1 \delta_{1i} - \hat{\sigma}_{u2}{}^2 z_i'\hat{\gamma}_2 \delta_{2i} - [\hat{\sigma}_{u1}\delta_{1i} - \hat{\sigma}_{u2}\delta_{2i}]^2 - [2\hat{\sigma}_{u1}\hat{\sigma}_{u2} - \hat{\rho}(\hat{\sigma}_{u1}^2 + \hat{\sigma}_{u2}^2)]$ $\dfrac{b(z_i'\hat{\gamma}_1, z_i'\hat{\gamma}_2, \hat{\rho})}{B(z_i'\hat{\gamma}_1, z_i'\hat{\gamma}_2, \hat{\rho})}$, where

$$\delta_{ki} = \frac{\phi(z_i'\hat{\gamma}_k)\Phi\left((z_i'\hat{\gamma}_h - \hat{\rho} z_i'\hat{\gamma}_k)/\sqrt{1-\hat{\rho}^2}\right)}{B(z_i'\hat{\gamma}_k, z_i'\hat{\gamma}_h, \hat{\rho})} \text{ for } k,h = 1,2 \quad k \neq h.$$ [11]

To specify the equilibrium bid function, four project-specific characteristics are included in $X$: length of roads (*LENG*), number of lanes (*LANE*), engineering cost estimates (*COST*) and expected contract duration (*MONTH*). These aim to control physical differences in road contracts. To mitigate unobservable heterogeneity across countries, the country-specific fixed effects are also included in $X$.

To deal with bidder heterogeneity, $X$ includes a number of dummy variables representing bidder nationalities. Whether bidders are domestic or foreign is among the most important determinants of the bid strategy in international competitive bidding (ICB). The ICB method is applied to large infrastructure projects assisted by donors. While local firms tend to have the cost advantage, foreign companies may have more skills and experience of similar types of projects in other countries. Another important bidder-specific factor that determines the bidders' cost (dis)advantage is the amount of backlog that each firm has, which is denoted by *BKLG*. This is calculated based on the contract amount awarded to each firm in the three-year period before a particular contract is auctioned. If firms form a joint venture, the average backlog among consortium members is used. The equilibrium bid is expected to increase with the amount of backlog. The reason is that if a firm has substantial job backlog, it may bid anyway but put in a high bid because the opportunity cost of undertaking additional public work is high (e.g., Porter and Zona 1993).

Of particular note, our backlog variable *BKLG* is merely a proxy of the actual amount of backlog held by a firm, because it is calculated only in our sample data. Our sample is not comprehensive. It represents several percentage points of the total ODA that is allocated to the transport sector all over the developing world. In

[11] See Tunali (1983) for a full derivation.

addition, governments may finance road projects with their own resources. To complement this, therefore, the amount of total transport ODA disbursed to each country is also adopted in *X*. This is calculated based on disbursement data in the three-year period prior to each auction (*CAID*).[12] When firms are already devoted to other road projects elsewhere, fewer bidders might bid on new public work. Even if they enter the market, their bids will be high, because their marginal costs for the work will be high.

Finally, following the traditional empirical auction literature, the number of bidders, *N*, is included in *X*. This is defined by the number of firms that were qualified if the prequalification procedure was applied. If not, it is the number of firms that simply submitted bids. Thus, *N* basically represents the number of bidders that are seriously interested in public work being contracted out. From the theoretical point of view, an important assumption is that the number of bidders is common knowledge among bidders prior to the bid submission. Our defined *N* is considered as a good proxy of this. In the ODA-financed projects, transparency in procurement is generally high. The list of prequalified firms is normally published before price bids are invited.

The coefficient of *N* is expected to be negative, if the traditional competition effect is captured.[13] Auction theory discusses the endogeneity of *N* in both theoretical and econometrical terms (e.g., McAfee and McMillan 1987; Porter and Zona 1993; Levin and Smith 1994; Bajari et al. 2009). From the empirical perspective, one of the simplest techniques to avoid this endogeneity problem is to relate the realized (not potential) number of bidders to explanatory variables in a Poisson or negative binomial regression model (e.g., Li and Perrigne 2003; Ohashi 2009). Then, the predicted number of bidders is substituted for the observed number of bidders. The current paper relies on the same technique.

To specify the selection processes, two external variables are additionally adopted in *Z*: rule of law (*RULE*) and control of corruption (*CORR*).[14] These governance

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[12] *CAID* is expected to capture the broader market conditions than *BKLG*. The used aid data come from the OECD Creditor Reporting System database.

[13] 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. See the following section. The competition effect is normally specified in 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 models often better fit actual auction data (e.g., Porter and Zona 1993; Gupta 2001, 2002).

[14] *X* is also part of *Z* except for *N*, because at the pre-selection stage, participants may not know how many firms will finally decide to participate in the competition.

indices come from the Worldwide Governance Research Indicators database (Kaufmann et al. 2008). Governance is an important challenge in public procurement (e.g., Olken 2007; Ware et al. 2007). In the public procurement context, the two selected indices are considered of particular relevance to the firms' entry decision, rather than the bidding strategy. An enterprise survey in Nigeria shows that the majority of potential contractors decided not to enter the public procurement market, because they do not trust the government's selection process (World Bank 2008). Under corrupt circumstances, efficient enterprises are discouraged from participating in public tendering (Burguet and Che 2004). Moreover, without reliable judicial systems firms cannot expect reasonable arbitration if any conflict occurs.

Governance may also influence the auctioneer's decision-making as well. A crucial shortcoming of multidimensional auctions involving quality consideration is that the award process tends to be less transparent and more vulnerable to corruption; authorities can easily exploit their excessive discretion in selecting particular contractors (e.g., Estache et al. 2009). This is why too exclusive specifications are normally prohibited in public procurement (Ware et al. 2007). According to this view, good governance will allow governments to enhance competition. On the contrary, one may think that governments with good governance will succeed in qualifying only those who have adequate capacity to undertake public work, avoiding excess competition (e.g., ADB 2006). If this is the case, the number of qualified firms would decrease with governance.

Table 1 shows the summary statistics. Our sample covers 285 firms that were potentially interested in 31 road procurement auctions under 11 projects in nine developing countries.[15,16] About 70 percent of the firms applied for the tendering process; while 196 firms applied for the qualification process, 89 firms did not. Then, about 60 percent of the applicants were identified as those who were technically responsive; 117 firms passed the technical examination, and 67 firms were disqualified. No data on qualification are available for 12 bidders. Not all of the qualifiers participated in the final price competition. About 15 percent did not. As the result, we observe only 98 winning and losing bids on 31 road contracts, of which the average contract value is about 23 million U.S. dollars. Note that both winning and losing bids are equally informative to estimate the equilibrium bid function, because

[15] Nine countries are Republic of Congo, Ethiopia, Ghana, Mauritania, the Philippines, Sri Lanka, Tanzania, Vietnam, and Zambia.

[16] Our sample originally covers about 450 potential bidders but is reduced to 285 due to missing relevant data.

the auction format used in infrastructure projects is the standard first-price sealed-bid auction. Data on losing bids are included whenever they are available.

The contracts in our sample differ considerably in both financial and technical terms. While low bids are less than 0.4 million U.S. dollars, high bids exceed 100 million U.S. dollars. The average length of roads is about 46 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 about two years. The average of total contract amounts obtained by a firm in the three-year period prior to the auction is about 9 million U.S. dollars. But again, there is huge variation; some firms undertook multiple projects in the past, and others have never been awarded before. Each recipient country seems to receive a considerable amount of aid in the transport sector alone. The governance indices are relatively low in the sample countries but differ across countries. The last three variables are country-specific but time-variant.

**Table 1. Summary statistics**

| Variable | Abbr. | Obs. | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|---|
| Evaluated bid 1/ | *BID* | 98 | 22.66 | 23.94 | 0.37 | 115.37 |
| Dummy for applicants to the process | $d1$ | 285 | 0.69 | 0.46 | 0 | 1 |
| Dummy for the technically qualified | $d2_a$ | 273 | 0.43 | 0.50 | 0 | 1 |
| Dummy for bidders of which bids are compared | $d2_b$ | 285 | 0.34 | 0.48 | 0 | 1 |
| Number of bidders proceeding to the price bidding stage | $N$ | 31 | 5.84 | 2.02 | 2.00 | 11.00 |
| Length of roads (km) | *LENG* | 31 | 46.30 | 62.00 | 0.90 | 278.55 |
| Number of lanes | *LANE* | 31 | 2.58 | 1.06 | 2.00 | 6.00 |
| Engineering cost estimate 1/ | *COST* | 31 | 20.36 | 36.43 | 0.39 | 176.74 |
| Estimated contract duration (months) | *MONTH* | 31 | 25.36 | 14.73 | 9.00 | 45.00 |
| Firm's backlog in the past three years 1/ | *BKLG* | 285 | 8.83 | 25.85 | 0.00 | 189.10 |
| Total transport aid received by the project country 1/ | *CAID* | 31 | 306.48 | 307.93 | 5.73 | 1,000.97 |
| Governance index 1: Rule of law | *RULE* | 31 | -0.59 | 0.25 | -1.22 | 0.01 |
| Governance index 2: Control of corruption | *CORR* | 31 | -0.74 | 0.21 | -1.09 | -0.18 |

1/ In millions of constant 2000 U.S. dollars.

## IV. Estimation results and implications

Table 2 presents the censored bivariate probit result as a first stage regression. The correlation between the two error terms in the selection equations is found to be negative; the bidders' participation decision-making is negatively related to the auctioneer's qualification decision. This is consistent with a theory of selection based on correlated cost and quality. Low-cost firms are more likely to enter the market, but they are also more likely to be disqualified by the auctioneer. This highlights an important tradeoff between quality and price in the public procurement systems. If governments were not concerned about the quality of projects, they could select the lowest cost contractor among a number of firms that entered the market with very competitive prices. But low-cost firms may not deliver high quality of work. Therefore, the auctioneer's qualification decision will have to play an important role, particularly in large-scale projects.

Larger road projects are found to have attracted fewer contractors. The coefficients of *LENG*, *LANE* and *COST* are broadly negative if they are significant. These variables are considered to be highly collinear with one another and thus have the same implication; there are a relatively small number of firms that can undertake large-scale road projects. Based on the selection equation of $d1$, fewer firms enter the market if the estimated engineering costs are large. On the other hand, the coefficients of *LENG* and *LANE* are negative and significant in the selection equation of $d2$, meaning that firms are less likely to be qualified for larger contracts. This is because auctioneers are likely to put more emphasis on bidders' technical capacity, when a large public work is procured. As the result, the joint likelihood of bidder participation and qualification will decrease with the size of contracts.

The coefficients of *BKLG* are both significantly positive in the two selection equations. This means that auctioneers are more likely to qualify bidders that have similar work experience in this market. In addition, bidders are more likely to enter in the tendering, when they were awarded some road projects in recent years. The result is not surprising, because the prequalification process normally requires firms to have experienced similar development projects in the past. This is a natural preference of governments for experienced and reputable contractors. Governments cannot take a risk of contracting with new entrants with no past experience and endangering the quality of public work, regardless of possible savings of procurement costs.

Notably, however, there is a marked contrast between the coefficients of *BKLG* and *CAID* in the bidders' entry decision. The coefficient of *CAID* is found negative.

This may be able to be interpreted to as the effect of capacity constraints of the whole road construction industry. Firms are less likely to enter the public procurement market if they are occupied with other jobs outside the market. A policy implication is clear: Auctioneers prefer to contract with experienced firms, but skilled contractors may already have been devoted to other jobs. This will pose a challenge for developing countries, because their local business markets are often thin. Without further development of local capacities, it would be difficult to improve the quality of public work, while containing public procurement costs.

Table 2 also shows that governance is an important element in the public procurement systems. But the result looks mixed, possibly due to imperfectness of the governance variables adopted. The coefficient of *CORR* is significant and positive in the bidder entry decision equation. This is consistent with expectations; if strong anticorruption policies are in place, more firms would participate in public tendering because they can expect fair competition. By contrast, from the auctioneer's point of view, fewer applicants are qualified under better anticorruption circumstances; the coefficient of *CORR* is found negative for $d2$. This is contradictory to the view that corrupt governments might abuse qualification to weed out serious competitors from the market. It seems more consistent with a view that auctioneers with good anticorruption policies would succeed in narrowing down applicants to only those who are capable enough.

Using the above bivariate probit as the first stage, the equilibrium bid function is estimated by the double selection model (Table 3). The first column model is a simple OLS estimation, which may be biased for two reasons: uncontrolled endogeneity associated with the number of bidders and uncontrolled selectivity bias. To deal with the first problem, the negative binomial regression model is used, by which the number of bidders is replaced with its predicted value $\hat{N}$.[17] The result is shown in the second column model. However, this may still be inconsistent, because of the selectivity bias caused by the two inverse Mill's ratios added.

The last column shows the consistent double selection estimator with the standard errors adjusted. It is found that the coefficients of the two inverse Mill's ratios are opposite. The one from the bidders' self-selection equation is negative, and the other

[17] The realization of $N$ is found to be mainly dependent on two factors: *COST* and *CAID*. Both have negative and significant coefficients. This is consistent with the other findings of this paper. Fewer firms would enter the market if a contract is large. If firms are presumably devoted to other jobs, the number of applicants would be smaller.

from the auctioneer's qualification equation is positive.[18] The result appears reasonable if the error term in the bid equation is considered to contain an unobserved component of the contractor cost. High-cost firms are less likely to decide to enter the market, because they know that their equilibrium bids tend to be high and lose the competition. On the other hand, auctioneers would more often qualify these high-cost firms,

**Table 2. Censored bivariate probit model for bidders' entry and auctioneer's rejection decisions**

| Dependent variable | *d*1 | *d*2 |
|---|---|---|
| ln *LENG* | 0.420 | –0.688*** |
| | (0.324) | (0.269) |
| *ln LANE* | 0.407 | –1.651** |
| | (0.862) | (0.724) |
| ln *COST* | –0.697** | –0.227 |
| | (0.353) | (0.153) |
| ln *MONTH* | 5.686* | –0.355 |
| | (3.370) | (1.003) |
| ln *BKLG* | 0.210*** | 0.022** |
| | (0.027) | (0.010) |
| ln *CAID* | –2.285* | 0.843 |
| | (1.246) | (0.537) |
| *RULE* | –0.348 | 2.231 |
| | (4.247) | (1.977) |
| *CORR* | 10.730*** | –7.857*** |
| | (3.242) | (2.823) |
| Constant | 6.260** | –2.702 |
| | (2.623) | (2.418) |
| $\rho$ | –0.194 | |
| Obs. | 285 | |
| Wald-chi$^2$ | 8.50E+06*** | |
| No. of country dummy variables | 4 | |
| No. of bidder nationality dummy variables | 16 | |

Note: The dependent variables are the bidder's entry decision and auctioneer's qualification decision. The robust standard errors are shown in parentheses. *, ** and *** indicate the 10%, 5% and 1% significance levels, respectively.

[18] Both coefficients appear statistically insignificant at least at the conventional significance levels. However, the inclusion of the inverse Mill's ratios is still considered to be important. The $p$-value is estimated at 0.12 for the coefficient of $\lambda_1$. Moreover, the double selection model is found to be systematically different from the OLS model in a statistical sense. The hypothesis can be rejected by the standard chi-square test. The test statistic is 44.41, which is well above the conventional critical values.

because the quality of their work is expected to be high. But a drawback is that their offered prices are also high. This is captured by the positive coefficient of $\lambda_2$.

The estimated bid function also reveals that larger contracts cost more. *LENG* has a positive coefficient; longer roads are more expensive. *LANE* also has a positive coefficient; wider road contracts are more costly. The findings are intuitively logical.

**Table 3. Equilibrium bid function by OLS and two-step double selection model**

| | OLS | OLS | Double selection model |
|---|---|---|---|
| ln *N* | –0.718** | | |
| | (0.284) | | |
| ln $\hat{N}$ | | –2.773** | –2.554* |
| | | (1.274) | (1.468) |
| ln *LENG* | 0.156* | 0.563** | 0.463* |
| | (0.094) | (0.218) | (0.293) |
| ln *LANE* | 1.682*** | 2.247*** | 2.037*** |
| | (0.247) | (0.441) | (0.590) |
| ln *COST* | 0.359*** | 0.121 | 0.131 |
| | (0.083) | (0.179) | (0.199) |
| ln *MONTH* | –0.293 | 2.095* | 1.898 |
| | (0.452) | (1.268) | (1.471) |
| ln *BKLG* 1/ | –7.194** | 0.475 | –3.013 |
| | (3.547) | (4.813) | (5.929) |
| ln *CAID* | 2.486*** | 1.044 | 1.215 |
| | (0.538) | (0.854) | (0.952) |
| $\lambda_1$ | | | –0.266 |
| | | | (0.173) |
| $\lambda_2$ | | | 0.224 |
| | | | (0.344) |
| Constant | 5.422** | 3.942 | 3.958 |
| | (2.679) | (2.757) | (3.140) |
| Obs. | 98 | 98 | 98 |
| R-squared | 0.953 | 0.9517 | 0.9535 |
| F-statistics | 72.92 | 71.36 | 65.99 |
| No. of country dummy variables | 6 | 6 | 6 |
| No. of bidder nationality dummy variables | 8 | 8 | 8 |

Note: The dependent variable is the bid amount in logarithm. The standard errors are shown in parentheses. *, ** and *** indicate the 10%, 5% and 1% significance levels, respectively. 1/ Multiplied by 1,000 for presentation purposes.

Notably, however, the coefficient of the engineering cost estimate is insignificant and well below one. This is because of its collinearity with other size-related project characteristics, such as length of roads. Part of the size effect seems to have already been absorbed by these size-related variables. The estimated small coefficients associated with the cost estimate variable are also attributable to the donors' tendency toward overestimation of project costs. Our cost estimates mostly come from the donors' project appraisal documents. Given the chronic cost overruns in infrastructure projects, donors tend to overestimate the project costs as a precautionary measure.

## V. Robustness

To check the robustness of our estimates, first, a sequential response model is employed. A critical assumption of the model is that a series of decisions are assumed independent of each other (e.g., Amemiya 1975; Maddala 1983). Unlike the censored bivariate probit technique, this model ignores the important correlation between the bidders' participation decision and the auctioneer's qualification decision. Nonetheless, the sequential response model allows to examine in more detail how prospective firms determine to participate in each step of the auction and how the auctioneer rejects some of the applicants. In the following analysis, three decision nodes are considered. First, bidders decide whether or not apply to the competition; this is the same as the above $d1$. The second decision $d2$ is separated further into two stages: $d2_a$ and $d2_b$. The auctioneer can determine to technically qualify each applicant prior to the price comparison ($d2_a$). Then, qualified bidders can decide whether to proceed to the price competition ($d2_b$).[19]

Assuming the normal distribution, the probabilities of decisions $d1$, $d2_a$ and $d2_b$ can be written by:

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

[19] In the above censored bivariate probit model, $d2$ 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 minimal in the sample.

Since these are sequential decisions, the parameters can be estimated by performing the probit model with only the relevant subsample in each case, if the random factors of these decisions are independent of each other.

Table 4 presents these three probit results, which are broadly consistent with the bivariate probit result.[20] As discussed, bidders are less likely to enter in the tendering, when their potential backlogs are large outside the market; the coefficients of *CAID* are significant in the first and last models. Auctioneers are more likely to qualify bidders that have more experience in the market (*BKLG*). All the indications are that potential contractors are resource-constrained, while auctioneers prefer to contract with experienced firms.

Larger road projects are found to have attracted fewer contractors. The coefficients of *LENG*, *LANE* and *COST* are broadly negative in all the models. Governance is found to exhibit slightly different results. The coefficients of *RULR* and *CORR* tend to be positive and significant. With solid rule of law and anticorruption policies, firms are more willing to participate in public tendering with confidence. If strong anticorruption policies are in place, more firms are induced to enter the market. And governments are also qualifying more firms. The evidence seems to be compatible with the general expectation that good governance would promote market competition, resulting in lower public procurement costs.

Another robustness issue is about the competition effect, which has been found significant in the estimated bid functions (Table 3). The OLS estimation, though potentially biased, has a significant, negative coefficient on *N*. Even if the endogeneity of bidder participation is controlled by replacing the number of bidders with its predicted value, the coefficient is still estimated to be negative and significant. In the double-selection model, the coefficient is estimated at –2.55, which is also statistically significant. The results appear consistent with the traditional auction literature (e.g., Brannman et al. 1987; Gupta 2002).

There is a counterview that the competition effect will be small (in absolute terms) if the selection process is successful in identifying the contractors with competitive prices and high technical competence. A successful self-selection and screening process

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[20] Some of the country- and nationality-specific fixed effects are omitted, if the fitted probability that one of the country or bidder nationality dummy variables equals unity is exactly either one or zero. The inclusion of such fixed effects means that the corresponding observations would simply be discarded. For instance, we observe three countries where some of the firms who purchased bidding documents did not apply to the selection process: Ghana, Vietnam and Zambia. In these countries, there is no case where some bidders from a country entered the market but others from the same country did not. Hence, no bidder nationality dummy variables can be included in the probit model for *d*1.

will leave a small number of participants in the price competition. Hence, the competition effect may not have a significant impact on the bid strategy. To examine this, a partially nonlinear regression is employed where the observed bids are regressed on dummy variables for each $N$ in the sample, denoted by $D(N = k)$.[21] As per Rezende (2005), the mapping between winning bids and the number of bidders is never linear.

**Table 4. Sequential binary response model for bidder participation**

| Dependent variable | $d1$ | $d2_a$ | $d2_b$ |
|---|---|---|---|
| ln *LENG* | –0.234 | –0.714** | –0.576*** |
| | (0.168) | (0.305) | (0.200) |
| ln *LANE* | –0.343 | –2.175 | –1.187* |
| | (0.609) | (1.365) | (0.703) |
| ln *COST* | –0.341* | –0.299 | –0.078 |
| | (0.201) | (0.299) | (0.252) |
| ln *MONTH* | 1.492 | 2.587 | 0.197 |
| | (1.614) | (3.463) | (1.854) |
| ln *BKLG* | | 0.020** | 0.008 |
| | | (0.008) | (0.012) |
| ln *CAID* | –1.848** | –2.507 | –1.759*** |
| | (0.910) | (2.330) | (0.683) |
| *RULE* | 5.819* | 12.210 | –6.071* |
| | (3.564) | (10.328) | (3.422) |
| *CORR* | 13.333** | 27.977* | –0.317 |
| | (4.503) | (17.117) | (1.837) |
| Constant | 22.655*** | 45.539* | 10.447** |
| | (8.357) | (27.135) | (4.658) |
| Obs. | 252 | 184 | 117 |
| Wald-chi$^2$ | 122.25*** | 75.64*** | 111.00*** |
| No. of country dummy variables | 3 | 4 | 0 |
| No. of bidder nationality dummy variables | 0 | 9 | 5 |
| Chi$^2$ test statistics: | | | |
| $H_0$: Coef. of country and bidder nationality dummies=0 | 30.78*** | 20.75* | 5.62 |

Note: 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.

[21] There is only one observation for which the number of bidders is two. Therefore, this is merged with the case of $N = 3$. The baseline are the cases where the number of bidders are equal to 10 or 11. There is no observation for which $N = 8$.

**Table 5. Alternative specification for *N*: equilibrium bid function**

| | Partially non-parametric | | Without *N* | |
|---|---|---|---|---|
| | OLS | Double selection model | OLS | Double selection model |
| D(*N*=2, 3) | 2.323*** | 2.338*** | | |
| | (0.585) | (0.875) | | |
| D(*N*=4) | 2.065*** | 2.076*** | | |
| | (0.532) | (0.835) | | |
| D(*N*=5) | 1.559*** | 1.591* | | |
| | (0.554) | (0.840) | | |
| D(*N*=6) | 1.806*** | 1.847** | | |
| | (0.555) | (0.839) | | |
| D(*N*=7) | 2.179*** | 2.208*** | | |
| | (0.554) | (0.837) | | |
| D(*N*=9) | 0.632** | 0.688* | | |
| | (0.314) | (0.400) | | |
| ln *LENG* | 0.184* | 0.175 | 0.135 | 0.014 |
| | (0.094) | (0.148) | (0.097) | (0.175) |
| ln *LANE* | 1.514*** | 1.492*** | 1.425*** | 1.167*** |
| | (0.229) | (0.341) | (0.233) | (0.394) |
| ln *COST* | 0.510*** | 0.511*** | 0.481*** | 0.451*** |
| | (0.084) | (0.097) | (0.069) | (0.096) |
| ln *MONTH* | 0.169 | 0.171 | | |
| | (0.391) | (0.448) | (0.461) | (0.622) |
| ln *BKLG* 1/ | –8.205*** | –11.068** | –6.545* | |
| | (3.055) | (4.826) | (3.660) | (6.406) |
| ln *CAID* | 2.496*** | 2.594*** | 2.478*** | 2.504*** |
| | (0.488) | (0.572) | (0.557) | (0.753) |
| $\lambda_1$ | | | | |
| | | (0.153) | | (0.218) |
| $\lambda_2$ | | 0.018 | | 0.418 |
| | | (0.314) | | (0.410) |
| Constant | 0.062** | | 5.111* | 5.417 |
| | (2.392) | (3.152) | (2.769) | (3.814) |
| Obs. | 98 | 98 | 98 | 98 |
| R-squared | 0.969 | 0.969 | 0.949 | 0.951 |
| F-statistics | 88.86 | 81.84 | 71.23 | 66.49 |
| No. of country dummy variables | 6 | 6 | 6 | 6 |
| No. of bidder nationality dummy variables | 8 | 8 | 8 | 8 |

Note: The dependent variable is the bid amount in logarithm. The standard errors are shown in parentheses. *, ** and *** indicate the 10%, 5% and 1% significance levels, respectively. 1/ Multiplied by 1,000 for presentation purposes.

The result is shown in Table 5. Even if the functional form associated with $N$ is relaxed, the competition effect still stands; the coefficients of the dummy variables for $N$'s tend to broadly decline, as the number of bidders increases. In addition, the bid equation is estimated without $N$. This will be a valid specification under the hypothesis that the overall competition effect on the bid function is negligible. As shown in the table, some of the coefficients are somewhat changed but remain broadly similar to the previous result with the number of bidders included. More formally, the hypothesis that the coefficients are not systematically different between the two models with and without $N$ cannot be rejected according to the conventional Wald test. The test statistic is estimated at 3.02, which is below the critical values of the chi-squared distribution. Hence, the results can be interpreted to mean that the overall competition effect may not be important in estimating the equilibrium bid function. But when it is included in the empirical model, we can still find the conventional competition effect in the public road procurement auctions. Of particular note, this is a static competition effect given that the number of bidders is fixed (i.e., fixed-$n$ approach) and thus can be coexistent with the dynamic process of bidders' entry and technical qualification.

## VI. Conclusion

Public procurement is a dynamic and complex phenomenon. Infrastructure procurement is particularly challenging, because infrastructure contracts are very expensive and technically complicated. Accordingly, there has been a long alleged concern about limited competition as well as collusive bidding behavior in public infrastructure procurement. The paper casts light on the dynamic process of contractor selection in public road auctions. In the sample from developing countries, the number of potential applicants for public work declined from about 13 to 4 firms or bidders throughout the process. Some firms decided not to enter the market for some reason, and others were disqualified for technical reasons. For these firms no bid prices are observable. Because of this partial observability, the paper applied a double selection estimation procedure.

The estimation results are found consistent with a theory of selection based on correlated cost and quality. Potential contractors self-select to participate in competitive bidding, depending on their own cost structure and expected rivals' strategies. Low-cost firms are more likely to enter the market. But they are also more likely to be disqualified. This is because auctioneers prefer to contract with experienced firms. The evidence suggests an important tradeoff between quality and price that governments are faced with in public procurement. Inexperienced contractors are prone to enter the market with more competitive prices. However, governments try to avoid the risk of project failure and delays, which would cause significant economic and financial costs to the economy. Therefore, the auctioneer's qualification decision plays an important role, particularly in large-scale projects. If adequate technical requirements are set, firms become even more self-selective. Small contractors cannot meet the requirements instantaneously. These interactions explain why potential contractors often shrink dramatically in public infrastructure procurement.

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