

(UN) Bundling Infrastructure Procurement

Evidence from Water Supply and Sewage Projects

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Abstract

Competition in public procurement auctions in the water supply and sanitation sector is largely limited. This is partly because of high technical complexity and partly because of auction design flaws. The division of lot contracts is an important policy choice for auctioneers to achieve efficiency. In general, there is a tradeoff between competition in auctions and size of contracts. Larger works could benefit from economies of scale and scope, but large contracts might undermine competition. Using data on public procurement auctions for water and sewage projects in developing countries, this paper shows

that bidder entry is crucially endogenous, especially because it is determined by the auctioneer's bundling and unbundling strategy. If water treatment plant and distribution network works are bundled in a single lot package, competition would be significantly reduced, and this adverse entry effect would in turn raise the public procurement costs of infrastructure. There is no evidence of positive scope economies in the bidder cost structure. It is important to account for the underlying cost structure for designing efficient auction mechanisms.

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

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**(UN)BUNDLING INFRASTRUCTURE PROCUREMENT: EVIDENCE FROM
WATER SUPPLY AND SEWAGE PROJECTS**

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I. INTRODUCTION

Competition is the single most important factor to contain public procurement costs and perhaps discourage collusive bidding behavior and corrupt practices. However, many infrastructure projects seem to continue faced with considerable difficulties to intensify competition in the procurement process (Estache and Iimi, 2008a). This may be partly unavoidable because infrastructure projects are normally extremely valuable and highly customized.¹ However, there are still several simple measures that could potentially extend market competition but sometimes have not been exploited carefully.

The current paper revisits the problem of endogenous participation in auctions and the division into procurement lots in the water supply and sewage industry. In this sector, it is always of particular concern that the observed degree of competition has been limited. In the public-private partnership (PPP) context, less than five multinational water enterprises may have been dominant over the world (Foster, 2005).² Even in the traditional public procurement context, the degree of competition is in general limited (Estache and Iimi, 2008a).

There is a tradeoff between competition in auctions and size of contracts. Not many firms can apply for highly valuable contracts, because of financial and experiential constraints. Highly specific works (which are normally valuable as well) would also limit competition. On the other hand, infrastructure projects are normally expected to exhibit economies of scale and possibly economies of scope in preparation and implementation. Therefore, larger lot works could be procured at relatively low costs per unit, though fewer applicants may participate.

¹ Estache and Iimi (2008d) discusses the interactive effects among entry, quality and competition with data from public procurement auctions for electricity projects. These elements are closely related with one another.

² According to the Private Participation in Infrastructure (PPI) database, the top 10 percent largest firms—defined by the number of transactions that each company obtained—were awarded about half of total infrastructure PPP contracts. In the water industry, especially, a multinational French water service operator, Veolia Environnement (former Vivendi Environnement, or Compagnie Générale des Eaux), was alone awarded 51 contracts, and another French company, SUEZ (former Lyonnaise des Eaux), won 50 transactions in the developing world.

To enhance competition at auctions, in theory, it is an important choice for auctioneers whether to bundle or unbundle a set of relevant objects. If there are only two bidders for an arbitrary number of objects, the auctioneer should bundle all the objects to facilitate their competition against one another. Conversely, given a relatively large number of bidders, the auctioneer has a tendency to prefer to unbundle her objects (Palfrey, 1983). Chakraborty (2006) also shows that the costs for entry are sufficiently large, separate auctions become more preferable for the auctioneer, as the entry costs increase. Moreover, if the auctioneer can choose the level of entry costs at the optimal level, separate auctions are always be superior to the bundle auction, regardless of the entry costs.³

In practice, whether the lot (un)bundling promotes or hinders competition is crucially dependent on the cost structure of firms for producing or delivering the contracts (Grimm *et al.*, 2006).⁴ Infrastructure procurement contracts may not be perfectly identical but often closely related to each other. Therefore, sometimes a company is able to undertake more than one public contract together, which are potentially different and could be contracted out separately. Under such circumstances auctioneers will be faced with an important choice between competition and economies of scale and scope. Given highly heterogeneous potential bidders, the unbundling strategy may be attractive because it would encourage relatively small but specialized firms to participate in the bidding process (Grimm *et al.*, 2006). However, the potential scale and scope effects, which would realize if a single contractor is awarded multiple components, have to be sacrificed.

Under the bundling strategy, potential economies of scale and scope can be internalized in the bidding process. Large procurement lots are expected to have relatively aggressive bids

³ It is worth noting that these propositions cannot be overemphasized, because they hold under the circumstances with only two symmetric bidders. No general model has yet been developed with more than two players. In addition, these models may not be dynamic in the sense that the fixed- n setting is still presumed.

⁴ Entry is another important issue in designing public procurement lots. The lot division to designate some to new entrants may play a significant role in establishing a competitive marketplace (Klemperer, 2002; Grimm *et al.*, 2006). Estache and Iimi (2008c) also confirms the importance of encouraging entrants to participate in infrastructure auctions for containing government procurement costs.

per unit. Estache and Iimi (2008a) shows that infrastructure procurement exhibits significant economies of scale in the sense that procurement costs would decrease with physical attributes of development projects.⁵ At the same time, however, it cannot be ignored that the bidder entry decision is potentially affected by the size of contract. For instance, it is shown that the larger electricity generators are procured, the fewer bidders can participate (Estache and Iimi, 2008d).

The current paper casts light on possible economies of scale in implementing infrastructure development projects. It uses data from official development assistance (ODA) projects. Specifically, the water supply and sewage sector is analyzed where there are basically two types of main components in ordinary development projects: treatment plant, and transmission and distribution network. These may require different expertise and technical skills but sometimes are auctioned together as a single package. If economies of scope are significant, the equilibrium bid should be low for contracts involving the two types of work. By contrast, if they are by nature too different to implement together and there is little room for economies of scope, then the bundling should bring no significant effect on bids. Rather, if only a few firms are able to implement both, the bundling approach would crucially limit bidder participation, undermining competition at the auction level.

To estimate the effect of the lot division on the bid function, it is necessary to explicitly address the endogeneity of bidder participation, rather than relying on the traditional fixed- n approach where the number of bidders is assumed fixed and commonly known by bidders. This is obvious from the above discussion. The endogenous participation problem is a complex issue in auction theory, especially when other factors are involved, such as quality requirements and joint bidding practices (e.g., see Estache and Iimi, 2008b, 2008d). The following empirical analysis focuses on the endogeneity of the number of bidder n by the

⁵ For instance, the predicted procurement cost of roads per km would be about 0.5 million U.S. dollars on average, but it would be prohibitively high at more than 2 million U.S. dollars per km when less than 10 km of roads are procured. Similarly, the predicted construction cost of a water treatment plant with a capacity of 500,000 m³ per day is about 58 U.S. dollars per m³. However, it will cost 200 U.S. dollars per m³ if the procured capacity is only 100,000 m³ per day.

zero-truncated negative binomial regression and instrumental variable techniques. The remaining paper is organized as follows: Section II describes our data on procurement auctions for water and sewage projects and develops our empirical models to estimate the equilibrium bid function with endogenous participation. Section III presents and interprets our main empirical results.

II. COMPETITION AND (UN)BUNDLING IN WATER AND SEWAGE PROJECT PROCUREMENT

The market of official infrastructure development is huge. The OECD Development Assistance Committee (DAC) member countries are spending about 12 billion U.S. dollars for assisting infrastructure development in developing countries every year. The water and sanitation sector accounts for 3–4 percent of this. In 2006, the amount of gross ODA disbursement to the sector reached approximately 3.4 billion U.S. dollars. In general, traditional ODA projects are procured through the first-price sealed-bid competitive tenders, especially when the (expected) contract amount exceeds a certain predetermined threshold.⁶ Because of project-specific nature and institutional design of auctions, these auctions will be characterized as the independent private value paradigm in the following discussion.⁷

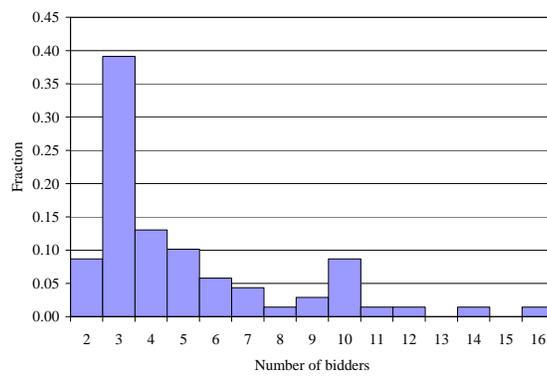
In general, competition in public procurement auctions for infrastructure development projects is limited (Gupta, 2002; Foster, 2005; NOA, 2007). In the water supply and sewage

⁶ There are a variety of procurement systems that involve different rules in practice, such as national preferences and technical evaluation process (e.g., Estache and Iimi, 2008d). However, regardless of such small discrepancies, the fundamental format for ODA project procurement is the first-price sealed-bid auction, exclusive of consultant procurement.

⁷ Empirically, it is debatable whether an empirical auction is characterized as the independent private or common value paradigm (e.g., Paarsch, 1992). In theory, they may lead to much different bidding patterns (e.g., Milgrom and Weber, 1982). Especially, in the latter setting, competition may increase the equilibrium bid due to the winner's curse effect (e.g., Klemperer, 1998). Our presumption is that project-specific asymmetric uncertainty across bidders seems to play a relatively important role to determine the individual bids, whence in favor of choosing the independent private value paradigm. For example, labor costs are different among firms. Equipment costs are also different because firms may have different sources of supply. In addition, the awarded contracts cannot be resold; thus, there is no common value of the project. With our data, there is no strong evidence that infrastructure procurement auctions exhibit common value characteristics, such as the winner's curse, as far as the bidding behavior associated with the number of actual bidders is concerned.

sector, the average number of bidders in an auction is about five.⁸ However, the distribution is skewed. Half of the auctions have only two or three bidders (Figure 1). Our data composed 69 procurement auctions in 12 developing countries may represent approximately 4 percent of total official development assistance (ODA) disbursement in the water supply water and sanitation sector; however, the general trend in this sector is not considered dramatically different from this.

Figure 1. Degree of Competition in ODA-Financed Water-Sector Projects



Source: Author's calculation.

The decision about whether to bundle or unbundle treatment and distribution lots appears to impact on bidders' auction participation and their submitted bid. If a treatment plant work is auctioned separately from any distribution work, the average number of bidding firms is 5.4, and the bids relative to their engineering cost estimates would average about 1.2 (Table 1). Similarly, about 5.2 bidders would participate on average if only distribution network work is contracted out. The average bid is about 1.1. These look all normal. Note that the distribution of the normalized bids is centered on unity (Figure 2). However, when both treatment and network works are procured simultaneously, the realized bids would be much higher and the bidder entry tends to be limited.

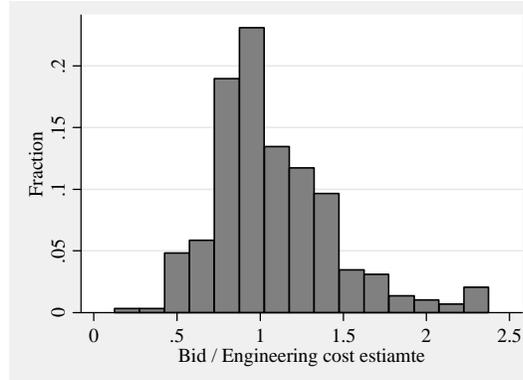
⁸ This level does not seem to be exceptional in general infrastructure procurements. The averages are 6.1 and 4.6 for road and electricity projects, respectively (Estache and Iimi, 2008a). The currently observed degree of competition is limited by and large.

Table 1. Competition, Bids and Bundling

	Number of bidders					Bid / Estimated cost				
	Obs.	Mean	Std.Dev.	Min	Max	Obs.	Mean	Std.Dev.	Min	Max
All	69	5.04	3.13	2	16	301	1.27	1.19	0.13	11.30
Only treatment plant work	21	5.43	3.37	2	14	90	1.19	0.32	0.53	2.28
Only distribution network work	35	5.23	3.29	2	16	167	1.08	0.39	0.51	2.56
Both	7	3.29	1.11	2	5	22	2.36	3.42	0.13	11.30

Source: Author's calculation.

Figure 2. Probability Distribution of Normalized Bids



Source: Author's calculation.

There are two possible reasons for high costs of the bundled approach, though related to one another. First the bundling might increase the entry cost for potential bidders, thus limiting participation and deteriorating auction efficiency (i.e., increasing the equilibrium bid).

According to the simple statistics in Table 1, the number of firms that can implement both seems to be small. This would obviously explain the relatively high bids, but maybe partly. For technical reasons, second, there might be no significant cost advantage of engaging the two different activities together. Rather, it could be more costly to internalize and coordinate them within a single company (i.e., diseconomies of scope). This might be the case if the required knowledge, skills and workers are not substitutable between the two works.

Conversely, if there are economies, it means that the observed bids would be rather higher without scope economies.

To estimate the (adverse) entry effect of bundling separately from the effect of bundling on the equilibrium bid through the underlying firm cost structure, a two-stage approach is used. Following the earlier empirical auction literature (e.g., Porter and Zona, 1993; Gupta, 2002;

Imi, 2006; Estache and Iimi, 2008d), the symmetric equilibrium bid of bidder i at auction j is considered:

$$\ln b = \alpha \ln n + \sum_k \beta_{x_k} \ln x_k + \frac{1}{2} \sum_k \sum_l \beta_{x_k x_l} \ln x_k \ln x_l + Z' \beta + \varepsilon_1 \quad (1)$$

where n is the number of participating bidders. The equilibrium function is expanded to accommodate the potential presence of economies of scope. An important simplification here is that the underlying firm cost structure is assumed to stand out in the bid function, and this is plausible under the conventional independent private value paradigm.⁹ x 's measure technical specifications of two different works: x_1 for treatment plant capacity in million m³ per day and x_2 for total length of water transmission and distribution pipes in km. If a contract covers only one of them, the rest is set at a very small but positive number (to avoid logarithms of zero). In this specification, the interactive coefficient, $\beta_{x_1 x_2}$, will capture the potential effect of scope (dis)economies.

Z contains other project-specific observables (which are commonly measured regardless of types of work) and bidder-specific characteristics. Specifically, the number of estimated working months (*MONTH*) and two dummy variables are included: D^{WATER} for water supply projects (as opposed to sewage and sanitation work) and D^{TE} for auctions with the bid evaluation system where prices are subordinated to technical assessment.¹⁰ If a greater

⁹ Under the independent private value paradigm, the well-known symmetric equilibrium bid (in the absence of entry costs) is $b(c_i) = c_i + \frac{\int_{c_i}^{\bar{c}} [1 - F(t)]^{n-1} dt}{[1 - F(c_i)]^{n-1}}$ where $c_i \in [\underline{c}, \bar{c}]$ is private cost information, which is identically distributed according to $F(c)$ for bidder $i = 1, \dots, n$. Therefore, if the cost structure potentially exhibits economies of scope, e.g., $c_i = g(x_1, x_2) + \theta_i$ where $\frac{\partial^2 g}{\partial x_1 \partial x_2} < 0$ and θ_i is a fundamental private value, then the equilibrium bid strategy may also be written as a function of $g(x_1, x_2)$. Of course, if there are diseconomies of scope, $\frac{\partial^2 g}{\partial x_1 \partial x_2} > 0$ and $\frac{\partial^2 b}{\partial x_1 \partial x_2} > 0$ likewise.

¹⁰ Typical are the prequalification and two-envelope procedures. Infrastructure project procurements often rely on such evaluation methods to exclude from the bidding process those who are likely to fail to implement the

emphasis is placed on technical considerations, the price bids would be normally higher (see Estache and Iimi, 2008d). Project country dummy variables are also included to the possible extent. Bidders' nationalities are included in Z to control for heterogeneity across bidders.

In Equation (1), n is a potentially endogenous variable, which is determined by x 's, Z and other exogenous variables W outside this system:

$$\ln n = \sum_k \gamma_{x_k} \ln x_k + \frac{1}{2} \sum_k \sum_l \gamma_{x_k x_l} \ln x_k \ln x_l + Z' \gamma + W' \delta + \varepsilon_2 \quad (2)$$

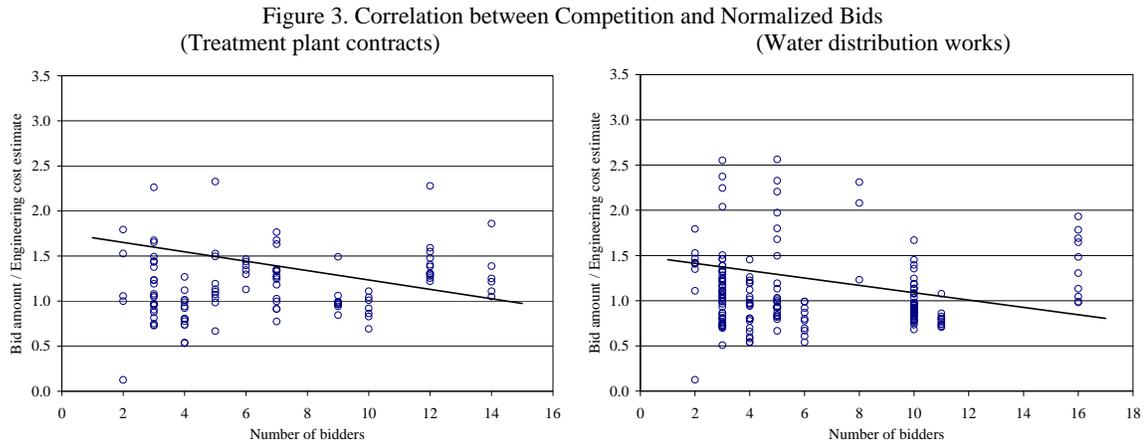
In an endogenous setting, auction theory suggests that there is the optimal number of bidders which equates bidders' entry costs with their expected profits when they participate (McAfee and McMillan, 1987; Levin and Smith, 1994). Following Porter and Zona (1993), Bajari *et al.* (2006) and Price (2008), two numbers are created for W : *CAID* is the amount of gross ODA disbursement in the water and sanitation sector that each project host country received for the three years before the award of a particular contract. *WAID* is similarly defined as the total ODA amount distributed to the water sector all over the developing world.¹¹ If firms are already engaged in a large number of similar development projects, fewer bidders would be willing to bid on further works. The aid data come from the OECD Creditor Reporting System database.

Two estimation methods are used. First, the traditional instrumental variable (IV) regression can estimate Equations (1) and (2) consistently. In addition, to see the importance of endogenous n , a truncated negative binomial model is also performed, because n is a nonnegative integer and typical of count data (e.g., Li and Perrigne, 2003; Ohashi, 2008). It is a generalized Poisson regression model. Notably, once the endogeneity associated with n is controlled, the (static) competition effect is still expected to be affirmative in theory (i.e.,

agreed contract. The fact that the substantial technical evaluation system was adopted is expected to capture unobservable but systematic technical difficulties in development works.

¹¹ Both are adjusted to constant 2005 U.S. dollar terms.

$\alpha < 0$). In our data, the normalized bid appears to decrease with the number of participants in both treatment plant and network cases (Figure 3).



Source: Author's calculation.

Our data are composed of 301 bids on 69 procurement auctions in 12 developing countries (Table 2). The dependent variable is the winning and losing evaluated (not read-out) bids in constant 2005 U.S. dollar terms.¹² Table 3 shows the summary statistics. The contract value varies from less than one million to 270 million U.S. dollars. The physical specifications of contracted work also widely differ. The treatment plant daily capacity could be 2,000 m³ in some cases and 600,000 m³ in other cases. The total length of erected pipes ranges from 5 km to 370 km, depending on contracts.

¹² Both winning and losing bids are considered equally informative in the first-price sealed-bid format, which is normally used in procurement auctions for development projects.

Table 2. Sample Coverage by Country

	Number of contracts	Number of bids
China	20	90
Croatia	4	20
India	5	11
Iran	6	38
Kazakhstan	1	2
Mexico	9	31
Morocco	1	6
Peru	4	16
Tanzania	4	12
Thailand	8	52
Viet Nam	3	7
Yemen	4	16
Total	69	301

Source: Author's calculation.

Table 3. Summary Statistics

Variable	Abbr.	Obs.	Mean	Std.Dev.	Min	Max
Bid amount 1/	<i>b</i>	301	14.95	23.64	0.33	276.66
Number of bidders	<i>n</i>	301	6.64	3.67	2.00	16.00
Dummy for technical evaluation	D^{TE}	301	0.72	0.45	0	1
Dummy for water supply projects	D^{WATER}	301	0.41	0.49	0	1
Treatment capacity (million m3 per day)	x_1	301	0.09	0.17	0	0.60
Total length of distribution pipes (km)	x_2	301	35.81	61.58	0	375.58
Engineering working months	<i>MONTH</i>	301	26.06	13.90	3.00	72.00
Past transport ODA in each country 1/	<i>CAID</i>	301	285	354	3	889
Past transport ODA in the world 1/	<i>WAID</i>	301	6,192	1,111	4,418	9,143

1/ In millions of constant 2005 U.S. dollars.

Source: Author's calculation.

III. ESTIMATION RESULTS AND IMPLICATIONS

The truncated negative binomial regression model indicates that the bidder entry, hence the number of bidders, is endogenously determined, particularly by the size of contract (Table 4). The null hypothesis that n is not affected by the explanatory variables in x 's, Z and W can be strongly rejected by the chi-squared test; the conventional Wald test statistics are estimated at 14.80 and 36.27. Especially, the variables for technical specifications in x 's are statistically significant. Based on the model with their quadratic terms, fewer bidders would participate in the competitive bidding for technically larger specifications. The elasticities are evaluated at mean values. Not surprisingly, this is supportive of the auctioneer's unbundling tendency toward smaller lot contracts to promote more competition in auctions.

It is also found that the bundling strategy would likely reduce bidder participation. The coefficient of $\ln x_1 \ln x_2$ is estimated at -0.005 , which is negative and significant. Therefore, the expected number of participants will decline as the sizes of involved treatment plant and network works increase simultaneously. It means that the number of firms that can implement both activities seems to be limited. This is important evidence to design the procurement auctions in this sector. The extent to which potential bidders are already occupied with other development projects may have a negative impact on bidder entry, but the coefficients are largely insignificant.

Table 4. Truncated Negative Binomial Regression on Number of Bidders

Dependent variable	<i>n</i>	<i>n</i>
D^{WATER}	-0.266 (0.261)	0.217 (0.284)
D^{TE}	0.033 (0.255)	0.201 (0.264)
$\ln x_1$	-0.009 (0.021)	0.284 (0.181)
$\ln x_2$	-0.020 (0.014)	-0.356 *** (0.092)
$(1/2)\ln x_1 * \ln x_1$		0.037 ** (0.019)
$\ln x_1 * \ln x_2$		-0.005 ** (0.002)
$(1/2)\ln x_2 * \ln x_2$		-0.045 *** (0.012)
$\ln MONTH$	-0.298 * (0.180)	-0.029 (0.175)
$\ln WAID$	-0.329 (0.761)	0.489 (0.653)
$\ln CAID$	-0.053 (0.068)	-0.098 (0.067)
Constant	5.205 (6.926)	-1.693 (5.780)
Obs.	69	69
Wald chi-squared	14.80 **	36.27 ***
Chi-squared test statistics:		
Ho: All $\ln x_1, \ln x_2 = 0$	2.44	27.59 ***
Implied elasticity:		
$(\partial n / \partial x_1)(n / x_1)$	-0.009 (0.021)	-0.093 *** (0.032)
$(\partial n / \partial x_2)(n / x_2)$	-0.020 (0.014)	-0.121 *** (0.029)

Note that the robust standard errors are shown in parentheses. *, **, and *** indicate the 10%, 5% and 1% significance levels, respectively.

Source: Author's calculation.

The IV estimation results confirm the above main findings about bidders' entry decision. The larger technical specifications are auctioned, the fewer bidders would participate. And the interactive term of treatment capacity and length of pipes has a significantly negative coefficient of -0.002 (Table 5).¹³ Therefore, the bundling strategy will harm bidder participation.

More importantly, the equilibrium bid has been found to decrease with the realized number of bidders in the IV specification, but that competition effect remains ambiguous in the ordinary least squares (OLS) estimation, which potentially provides biased estimates under the assumption that n is endogenous. In addition, the estimated bid function implies that there is no significant effect of economies of scope. The interactive coefficient estimated at 0.001 is far from significant in the IV regression. Interestingly enough, this term has a positive and significant coefficient of 0.004 in the OLS model. The results can be interpreted to mean that the overall impact of bundling the two components may be toward higher procurement bids and weaker market competition, as captured by the OLS estimate. However, this adverse effect can be explained largely by the entry deterrence effect resulting from bundling irrelevant works. If this entry effect is excluded, the equilibrium bid function still has the significant (static) competition effect (i.e., lower b for larger n). And there is no evidence of positive scope economies in the underlying bidder cost structure. The positive coefficient of $\ln x_1 \ln x_2$ must capture the above-mentioned endogenous negative entry effect.

The above policy implication is straightforward and may be consistent with intuitions that some practitioners already have. Nonetheless, the risk inherent in the bundling strategy, which is still very often preferred by auctioneers and financial sponsors (i.e., aid agencies) for various reasons, cannot be overemphasized. It is partially true that the unbundled procurement is administratively costly for executing agencies, because they may have to

¹³ The models include 13 dummy variables other than those shown in the table: one for aid donors, five for project host countries, and seven for bidder nationalities. Initially, there were more dummy variables included. However, many dummies have been found statistically insignificant due to multicollinearity. Therefore, several insignificant dummy variables are omitted; the null hypothesis of these coefficients being zero cannot be rejected at the conventional significance level. The F -statistics is estimated at 1.48 for the expanded IV model.

spend several times as much time as required in the turnkey procurement case. They also have to coordinate a number of small lots divided. However, our estimates indicate that the potential losses caused by this flawed bundling design could be sizable. If the truncated negative binomial regression model (the last column of Table 4) is evaluated at the sample means other than project capacity variables, x_1 and x_2 , the predicted number of bidders would be only 2.1 when bundled. If procured separately, the treatment and network component could attract 5 and 4.4 contenders, respectively (Table 6). This reduction in bidding participants from some 5 to 2 would lead to significant increases in government procurement costs according to the estimated bid function in Table 5.

Table 5. OLS and IV Regressions on Bids

Estimation method	OLS		IV		IV	
	ln <i>b</i>	ln <i>b</i>	1st stage ln <i>n</i>	2nd stage ln <i>b</i>	1st stage ln <i>n</i>	2nd stage ln <i>b</i>
ln <i>n</i>	-0.013 (0.100)	0.027 (0.089)		-1.523 ** (0.679)		-1.011 ** (0.439)
<i>D</i> ^{WATER}	0.114 (0.121)	-0.014 (0.135)	0.247 *** (0.092)	0.403 ** (0.201)	0.392 *** (0.093)	0.267 (0.203)
<i>D</i> ^{TE}	0.739 *** (0.114)	0.341 *** (0.107)	-0.089 (0.072)	0.461 ** (0.203)	0.037 (0.081)	0.330 ** (0.154)
ln <i>x</i> ₁	0.049 *** (0.010)	0.577 *** (0.094)	0.011 ** (0.006)	0.070 *** (0.011)	0.142 ** (0.068)	0.637 *** (0.136)
ln <i>x</i> ₂	0.022 *** (0.008)	0.1681 *** (0.038)	-0.006 (0.004)	0.007 (0.013)	-0.110 *** (0.027)	0.0288 (0.071)
(1/2)ln <i>x</i> ₁ *ln <i>x</i> ₁		0.054 *** (0.010)			0.017 ** (0.007)	0.062 *** (0.015)
ln <i>x</i> ₁ *ln <i>x</i> ₂		0.004 *** (0.001)			-0.002 *** (0.001)	0.001 (0.002)
(1/2)ln <i>x</i> ₂ *ln <i>x</i> ₂		0.016 *** (0.005)			-0.012 *** (0.004)	0.0002 (0.009)
ln <i>MONTH</i>	0.653 *** (0.109)	0.719 *** (0.118)	-0.578 *** (0.066)	-0.114 (0.338)	-0.476 *** (0.068)	0.334 * (0.200)
ln <i>WAID</i>			-0.803 *** (0.265)		-0.520 ** (0.258)	
ln <i>CAID</i>			0.200 *** (0.055)		0.235 *** (0.056)	
Constant	-0.645 (0.405)	1.057 ** (0.453)	8.489 *** (2.255)	2.721 * (1.552)	5.919 *** (2.210)	3.226 *** (1.032)
Obs.	301	301	301	301	301	301
<i>R</i> -squared	0.789	0.821	0.599	0.488	0.647	0.694
<i>F</i> -statistics	111.89	119.99	20.92	105.11	22.08	112.30
Recipient country dummy	Yes	Yes	Yes	Yes	Yes	Yes
Bidder nationality dummy	Yes	Yes	Yes	Yes	Yes	Yes
Donor dummy	Yes	Yes	Yes	Yes	Yes	Yes
Implied elasticity:						
(∂ <i>b</i> /∂ <i>x</i> ₁)(<i>b</i> / <i>x</i> ₁)	0.049 *** (0.010)	-0.032 (0.019)		0.070 *** (0.011)		-0.045 (0.029)
(∂ <i>b</i> /∂ <i>x</i> ₂)(<i>b</i> / <i>x</i> ₂)	0.022 *** (0.008)	0.063 *** (0.013)		0.007 (0.013)		0.015 (0.026)
(∂ <i>n</i> /∂ <i>x</i> ₁)(<i>n</i> / <i>x</i> ₁)			0.011 ** (0.006)		-0.033 ** (0.015)	
(∂ <i>n</i> /∂ <i>x</i> ₂)(<i>n</i> / <i>x</i> ₂)			-0.006 (0.004)		-0.037 *** (0.010)	

Note that the robust standard errors are shown in parentheses. *, **, and *** indicate the 10%, 5% and 1% significance levels, respectively.

Source: Author's calculation.

Table 6. Implied Entry Deterrence Effect of Bundled Procurement

Procured content		Projected number of bidders (Std. Err.)	
Treatment plant (<i>x</i> ₁)	Network (<i>x</i> ₂)		
74,909 m ³	41.4 km	2.088	(0.388) ***
74,909 m ³	Nearly zero	5.014	(0.898) ***
Nearly zero	41.4 km	4.379	(0.445) ***

Source: Author's calculation.

IV. CONCLUSION

Competition in procurement auctions for infrastructure projects has been largely limited. The water supply and sanitation sector is not exceptional. It is partly because of high technical complexity and partly because of auction design flaws. How to divide a project into lot contracts is an important policy choice for auctioneers. The paper examines the tradeoff relationship between competition in auctions and size of contracts. Larger works could benefit from economies of scale and scope, which are exhibited by large infrastructure projects in general. On the other hand, large contracts could mitigate competition if potential bidders are constrained by technical skills and other resources.

With the data on public procurement auctions for water and sewage projects in developing countries, it is shown that the bidder entry is perhaps endogenous, especially influenced by the bundling and unbundling strategy of potentially different types of contracts, such as water treatment plant and distribution network works. If these two activities are bundled in a single lot package, competition would likely be curbed significantly because there may be only a few firms that can implement both works together. This adverse entry effect would in turn raise the equilibrium bid, thus pushing up public procurement costs of infrastructure. There is no evidence of positive scope economies in the underlying bidder cost structure. Therefore, there is no rationale for bundling the water treatment plant and network components.

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