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

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ABSTRACT

Competition is often limited in public procurement for infrastructure projects. This is not only because of technological complexity of the projects but also because there are flaws in auction design. How to divide a project into lot contracts is an important policy choice for governments to foster competition and thus contain public procurement costs. In general, there is a tradeoff between the degree of competition and the size of contracts; larger contracts can benefit from economies of scale and scope but have to compromise competition. Using procurement data from water and sanitation projects in developing countries, this paper analyzes the effect of the auctioneer's (un)bundling strategy on bidders' entry and bid behavior. It is found that if two public tasks, such as water treatment plant and distribution network constructions, are bundled in a single lot package, competition would be restrained, raising the cost of public procurement. There is no clear evidence of positive scope economies between these two works in the bidders' cost structure. Therefore, in this specific case, there is no rationale of bundling the two types of public work into a single contract.

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

JEL classification: D44, H54, H57, C21.

INTRODUCTION

Competition is one of the most important factors for governments to contain public procurement costs and reduce the risk of collusive bidding behavior and corrupt practices. Particularly in infrastructure projects, competition seems to have long been a challenge for public procurers. In the U.S. highway construction auctions in Florida, the average number of bidders is about five, though with a wide range from 2 to 19 per auction (Gupta, 2002). In the case of Oklahoma road construction, the average number of bidding firms is only 3.3 (De Silva, Dunne, & Kosmopoulou, 2003). In developing countries, large-scale infrastructure projects attracted about six bidders on average (Iimi, 2006; Estache & Iimi, 2008). This is not only because infrastructure projects are technically complex and highly customized but also because of some institutional flaws in procurement design. There is still room to enhance market competition and thereby make public procurement more efficient.

The current paper applies the empirical auction theory with endogenous bidder participation to public procurement data from the water supply and sewage sector in the developing world. In this sector, it seems that active, potential market players have been especially limited. In the public-private partnership context, for instance, less than five multinational water enterprises seem to have dominated the global market (Foster, 2005).[1] Even in the traditional public procurement context, the degree of competition is largely limited (Estache & Iimi, 2008).

There is an important tradeoff between the size of contracts and the intensity of competition in auctions. On one hand, not many firms can apply for a consolidated, highly complex and valuable pubic contract, because contractors usually have resource constraints and may not be able to meet certain financial and experiential preconditions required. Without doubt high participation criteria are necessary and help auctioneers or governments to secure the quality of public works. But designing large-scale packages may severely limit market competition. On the other hand, infrastructure projects are normally expected to exhibit economies of scale and scope in procurement. Larger works can be delivered at relatively low costs per unit. Auctioneers can also minimize the administrative costs of tendering and supervision by having a few large packages. In sum, small contracts could contribute to fostering market competition but will have to sacrifice the possible benefits from economies of scale and scope in procurement.

To enhance competition in a competitive bidding process, in theory, it is an important choice for auctioneers whether to bundle or unbundle a set of relevant objects. As per Palfrey (1983), 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 its objects. Chakraborty (2006) also shows that if the costs for entry are sufficiently large, separate competitive biddings 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 competitive biddings are always superior to a bundled one, regardless of the entry costs.[2]

In practice, whether the lot (un)bundling promotes or hinders competition is dependent on the firm cost structure to undertake and implement public work (Grimm, Pacini, Spagnolo, & Zanza, 2006). There are a wide range of public works in the infrastructure sector, which may not be perfectly identical but closely related to each other. Therefore, companies are sometimes able to undertake several different tasks together, which can potentially be contracted out separately. Under such circumstances auctioneers will be faced with an important question of how to procure those public works. If potential bidders are highly heterogeneous, the unbundling strategy tends to be better because it would encourage relatively small but specialized firms to participate in a competitive bidding (Grimm, Pacini, Spagnolo, & Zanza, 2006). For political reasons, some governments may prefer to unbundle public work and promote local procurement; but it often turns out rather costly (e.g., Hyytinen, Lundberg, &Toivanen, 2006; Marion, 2007). This is because the potential scale and scope effects, which might be realized if multiple tasks are awarded to a single contractor, will have to be discarded.

Under the bundling strategy, potential scale and scope economies are expected to be internalized in the bidders' bid preparation process. If two or more tasks exhibit complementarities and are consolidated into a single contract, the equilibrium bid would be more competitive. If there are economies of scale, large procurement lots would have relatively aggressive bids per unit, as shown by Estache and Iimi (2008).[3] However, bundling may deter new contractors from entering the market if the size of a contract is too large with less relevant activities combined. Under standard settings, auction theory clearly suggests that limited competition would have an adverse effect on the public procurement costs.

An important issue from both theoretical and empirical points of view is that bidder participation is endogenous, in particular in our infrastructure procurement context. In theory, the bidder participation would become endogenous in the presence of a positive entry cost required from bidders (McAfee & McMillan, 1987; Levin & Smith, 1994; Menezes & Monteiro, 2000).[4] Econometrically, how to control for this endogeneity is an important issue (e.g., Porter & Zona, 1993; Bajari, McMillan, & Tadelis, 2009). Presumably, potential bidders are deciding whether or not to enter the market depending on characteristics of public works to be contracted out, their own constraints and rivals' bidding strategies. Estache and Iimi (2009a) show that the larger electricity generators are procured, the fewer bidders can participate.

This paper casts light on possible economies of scope in implementing infrastructure development projects, using data from official development assistance (ODA) projects. Specifically, the water supply and sewage sector is analyzed where two types of public works are mainly acquired: treatment plant development and distribution network installation. They may require different expertise and skills but can be contracted out together as a single package. To estimate the effect of (un)bundling the two components on the bidding strategy, we employ a conventional instrumental variable (IV) estimator with the endogeneity of bidder participation taken into account, rather than assuming the fixed-*n* approach. The zero-truncated negative binomial regression is also performed to obtain the predicted number of bidders. To check for robustness, the Kwoka's (2002) composite specification for economies of scope is applied, and the two-stage quantile regression (2SQR) is also estimated.

The remaining paper is organized as follows: Section II provides an overview of the ODA-related infrastructure procurement market and our used data in the water and sewage sector. Section III develops our empirical models to estimate the equilibrium bid function with endogenous bidder participation taken into account. Section IV presents our main empirical results and discusses several policy implications.

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

The market of official infrastructure development is significant. Every year the OECD Development Assistance Committee (DAC) member countries are spending more than 10 billion U.S. dollars for assisting infrastructure development in developing countries. The water and sanitation sector accounts for about 30 percent of this (Table 1). In 2006, about 3.8 billion U.S. dollars were committed and approximately 3.1 billion U.S. dollars were disbursed to this sector. However, the resources available for infrastructure development are still not sufficient, compared to the financial needs in the developing world (e.g., Fay & Yepes, 2003). In general, fiscal space could be created by revenue mobilization, expenditure reprioritization and efficiency gains in public spending (IMF, 2005; Heller, 2005; World Bank, 2005). Especially in infrastructure procurement, there have been alleged concerns about inefficiency and misprocurement (e.g., Olken, 2007; World Bank, 2008a). Hence, the possible efficiency gains would be significant through restructuring public procurement systems.

TABLE 1
Total Amount of ODA for Infrastructure Development

	2001	2002	2003	2004	2005	2006
Total amount of ODA commitment	54,580	62,207	76,362	73,935	94,407	95,286
Of which, infrastructure 1/	9,829	8,119	8,344	13,764	13,063	11,979
Of which, water supply and sanitation	2,609	1,629	2,479	3,155	4,466	3,799

1/ Including energy, water and sanitation, transport and storage, and communication.
Source: OECD Creditor Reporting System database.

ODA-financed projects are usually procured through the international competitive bidding, which follows a first-price sealed-bid format.[5] In addition, we characterize the traditional infrastructure procurement competitive bidding as the independent private value paradigm, because bidder-specific uncertainties are considered to play a relatively important role to determine the individual bids. Project-specific uncertainties common across bidders still exist, but maybe to a limited extent.[6] Under the independent private value paradigm, it is generally expected that competition would contribute to reducing the public procurement cost to the minimum possible market price. Note that governmental entities often do not know who the lowest responsive firm in the market is, when they procure goods, services and construction for public use from private contractors. This is a fundamental reason why they should rely on competitive bidding. If they knew the most efficient contractor or vendor, governments could negotiate directly with that firm. Under the assumption that contractors know their true costs of undertaking a public contract, it is predicted that no bidders reveal their true cost parameters. However, as the number of bidders increases, bidders would be induced to reveal their true costs because the probability that each bidder wins the contract declines (e.g., Milgrom & Weber, 1982; Wolfstetter, 1998).

In reality, however, competition in public procurement auctions for infrastructure development projects is limited (Gupta, 2002;

Foster, 2005; NAO, 2007). Our sample data are composed of 70 public tenders for 23 water supply and sanitation projects in 12 developing countries. The sample covers two types of public works in this sector: treatment plant construction and distribution network installation. On average 5.3 firms participated in a competitive bidding. In practice, the bidder participation is a complex and dynamic process. In this paper, we define the degree of competition by the number of bidders who were prequalified if applicable or actually participated in the bidding process otherwise.[7] The normalized bid averages about 1.2, relative to the engineering cost estimate (Table 2).

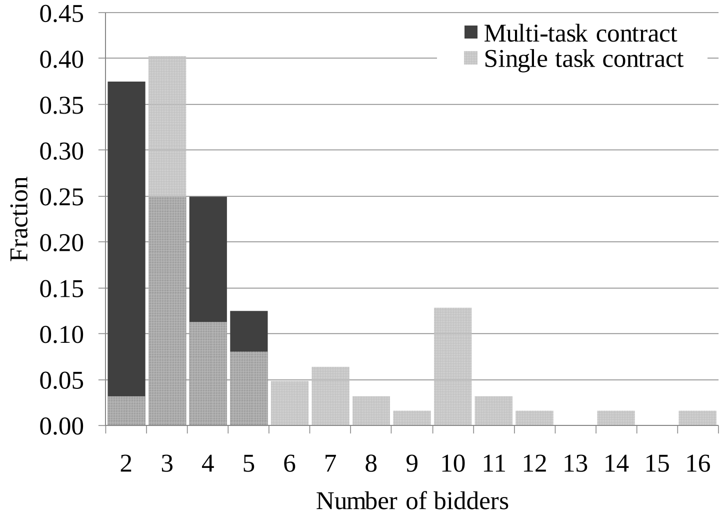
TABLE 2
Competition, Bids and Bundling

	Number of bidders					Bid / Estimated cost				
	Obs.	Mean	Std. Dev.	Min	Max	Obs.	Mean	Std. Dev.	Min	Max
All	70	5.31	3.26	2	16	299	1.19	1.03	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	41	5.68	3.36	2	16	185	1.05	0.40	0.45	2.56
Both	8	3.13	1.13	2	5	24	2.28	3.28	0.13	11.30

The decision about whether to bundle a treatment and distribution lot appears to have impacted significantly on both bidder participation and bidding strategy. If a treatment plant work is solely put out to tender, the average number of bidders is 5.4, and the relative bid would average about 1.2. Similarly, if only a distribution network task aims to be contracted out, about 5.7 bidders would participate on average. The average bid is low at about 1.1.

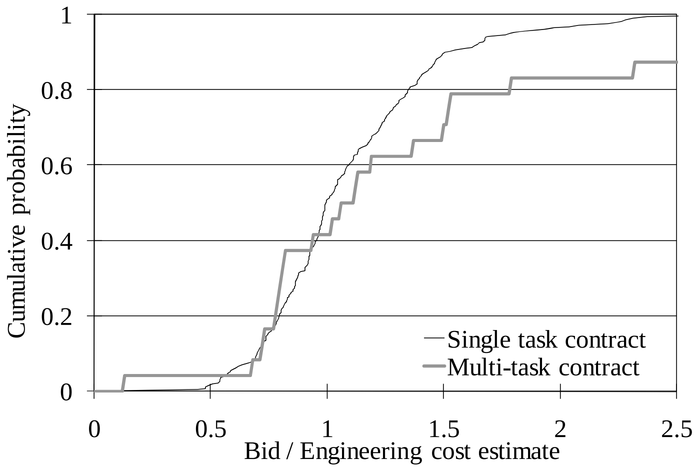
However, when the two tasks are procured simultaneously under a single contract, the bidder participation would become even more restricted to about 3 firms and the realized bids seem to have doubled to 2.3. Of course, means are potentially sensitive to some possible outliers, but distributions also indicate the same conclusion. Figure 1 illustrates the probability distributions of the number of bidders. While the distributions, conditional on the multitask contracts, are shown in dark gray, those conditional on the single-task package are shown in light gray.[8] It is clear that when the two tasks are bundled, the distribution of the number of bidders is highly concentrated on 2 to 4. By contrast, under the unbundling approach it may be possible to attract more than 10 bidders. Figure 2 compares the cumulative probability distribution functions of normalized bids between single- and multi-task contracts. The distribution conditional on the multiple tasks combined has thicker tails on both sides but seems to concentrate especially on the higher tail, meaning that bundled procurement would lead to higher government costs.

FIGURE 1
Probability Distribution of Number of Bidders



There are two possible reasons for high costs of the bundled approach. First, the bundling might increase the entry cost for potential bidders, thus limiting participation and pushing up the equilibrium bid. This may be likely as shown in Figure 1, but still explains partially. From the technical point of view, second, there might be no cost advantage for a firm to be engaged to the two different activities simultaneously. Rather, it could be more costly to internalize both activities 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 tasks and bidding companies are required to coordinate and connect the separate lots into the whole of the project at a high cost. These disadvantages will be built into the equilibrium bid for larger projects under the bundled procurement.[9]

FIGURE 2
Cumulative Probability Distribution of Normalized Bids



Of particular importance, in this market potential contractors are allowed to freely negotiate and collaborate with each other if they prefer to do so. Institutionally, any firm can bid independently or in joint venture confirming joint and several liability, either with domestic firms and/or with foreign firms.[10] In our data, 82 out of 299 bidders are identified as joint ventures (Table 3). For only water treatment plant construction works, 25 bidders jointly participated. For contracts of only water distribution network installation, 41 applicants were joint bidders. Therefore, about one-fourth of bidding firms already formed joint ventures even for a single task contract. In the case of contracts composed of both tasks, 16 out of 24 bidders participated jointly. Not surprisingly, for large multitask contracts, companies are more likely to collaborate with one another, pool their resources and thereby attempt to have the advantage in the competition. Accordingly, whether to bundle or unbundle the two tasks is not be predetermined by the industrial structure but chosen by governments at will. And bidders follow their decision through the joint bidding practices and enter the market if they want.

TABLE 3
Joint Bidding Practices

	Obs.	Number of joint bidders	(%)
All	299	82	27.4
Only treatment plant work	90	25	27.8
Only distribution network work	185	41	22.2
Both	24	16	66.7

EMPIRICAL MODEL AND DATA

To estimate the (un)bundling effects on the bidder participation and bidding strategies separately, the following conventional symmetric equilibrium bid function is considered based on the earlier empirical auction literature (e.g., Porter & Zona, 1993; Gupta, 2002; Iimi, 2006):

$$\ln BID = \alpha \ln NUM + \sum_k \beta_k \ln x_k + \frac{1}{2}\sum_k \sum_l \beta_{kl} \ln x_k \ln x_l + W'\gamma + \varepsilon_1 \qquad k,l = 1,2 \tag{1}$$

where *BID* is the amount of bid price, which is the evaluated cost, not necessarily the submitted (read out) price. Some technical errors are already corrected, and adjustments are made for any material and other quantifiable deviations from or reservations to the terms, conditions, and specifications in the bidding documents. On that basis, all bids observed in the sample are considered equally responsive.[11] *NUM* is defined by the number of prequalified bidders, as discussed in the previous section.

The equilibrium function is expanded to accommodate the potential effect of scope economies. This is an application of the traditional industrial organization literature focusing on economics of scope in production (e.g., Kwoka, 2002). 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.[12] x's measure technical specifications of two different works: x_1 and x_2. If a contract covers only one of x's, the other is set at a very small but positive number (to avoid logarithms of zero). Under this specification, the interactive coefficient, β_{12} , will capture the potential effect of scope (dis)economies. In our case, x_1 represents the treatment plant capacity in million m^3 per day (*TRET*), and x_2 measures the total length of water transmission and distribution pipes in kilometers (*PIPE*).

W contains other project-specific observables, which are commonly measured regardless of types of work, and bidder-specific characteristics. Project country dummy variables are also included, because the bidding and entry strategies may vary systematically across countries. To control heterogeneity among bidders, their nationalities are included in *W*. Besides these dummy variables, the number of estimated working months (*MONT*) and a dummy variable for water supply projects (*DWAT*), as opposed to sewage and sanitation work, are also included.[13]

In estimating Equation (1), there are two important econometric issues: small-positive-number bias and bidder entry endogeneity. First, in Equation (1) all covariate except dummy variables are specified as the logarithms. By construction, however, if a contract aims at a single task, either *TRET* or *PIPE* takes zero, thereby causing the log-of-zero problem. A common approach to deal with this problem is to replace zeros with a small positive value. However, one potential risk is that the small positive value translog estimator could generate severe bias when a considerable portion of the observations have zero values for *x*'s (e.g., Weninger, 2003). It may also be highly sensitive to the choice of a small value. By contrast, it is known that the Composite approach (e.g., Kwoka, 2002) has relatively low bias and the small standard deviation. In the following analysis, therefore, the robustness of our estimates will be checked by using the non-translog specification.

The second econometric issue is that the number of bidders is potentially endogenous. Therefore, the Ordinary Least Squares (OLS) regression would likely be biased. There are two approaches to deal with this problem. First, the number of bidders can be instrumented by exogenous variables that are uncorrelated with the error term ε_1 (De Silva, Dunne, & Kosmopoulou, 2003; Li & Perrigne, 2003; Li & Zheng, 2006; Ohashi, 2009). The second approach is the auction-specific fixed effects model (De Silva, Dunne, & Kosmopoulou, 2003). This, by construction, can control all observable and unobservable auction characteristics. However, the fixed effects model has a critical disadvantage; it does not allow us to estimate any marginal effect of auction-specific covariates, which are the center of interest in many cases. For example, the competition effect cannot be inferred because the number of bidders is one of the auction-specific variables.

Hence, the following analysis adopts the first instrumental variable (IV) approach. Two instruments are selected.[14] One is the total amount of backlogs in our sample—denoted by *BKLG*—which is calculated based on the contract amount awarded and the estimated project schedule. If firms form a joint venture, the average backlog among consortium members is used. Another is the total amount of official assistance in the water and sanitation sector disbursed to each project host country during the three-year period prior to each tender (*CAID*).[15] The original aid data come from the OECD Creditor Reporting System database.[16] These variables are in principle lagged variables and considered uncorrelated to the error term in the present bidding behavior.

$$\begin{aligned} \ln NUM = & \sum_k \delta_k \ln x_k + \frac{1}{2} \sum_k \sum_l \delta_{kl} \ln x_k \ln x_l + W' \phi \\ & + \lambda_1 \ln BKLG + \lambda_2 \ln CAID + \varepsilon_2 \end{aligned} \qquad (2)$$

The basic rationale of these instruments is twofold. On one hand, it is expected that if prospective contractors are already devoted to other development projects elsewhere, fewer bidders could bid on further new works simply because they might be busy (Porter & Zona, 1993; Bajari, McMillan, & Tadelis, 2009; Price, 2008). On the other hand, if development projects are technically complex and auctioneers prefer to contract with experienced companies, then these variables will augment bidder participation in competitive tendering. In fact, the prequalification process in ODA projects often requires prospective bidders to have experienced similar development projects in the past.

Three estimation methods are used. First, the conventional IV regression can estimate Equations (1) and (2) consistently. Second, a two-stage least-squares (2SLS) estimator using a truncated negative binomial model as the first stage regression is also performed, because the number of bidders is a nonnegative integer and typical of count data (e.g., Li & Perrigne, 2003; Ohashi, 2009). Note that in this case the dependent variable is the number of bidders, *NUM*, without taking the log. Finally, the quantile regression is also used to examine the potentially heterogeneous bidding behavior across levels of bids (De Silva, Dunne, & Kosmopoulou, 2003). While means, thereby the OLS regression, are sensitive to possible outliers, the quantile regression allows to estimate differences in the distribution of entrant bids more accurately. Notably, however, the quantile technique, even if differencing in quantile regression, cannot solve the endogeneity problem in bidder participation (Arias, Hallock, & Sosa-Escudero, 2001). Hence, the two-stage quantile regression (2SQR) estimator is performed. Five quantiles are examined to explore the difference across bids: .10 .25, .50, .75 and .90.

Our data are composed of 299 bids on 70 procurement auctions in water and sewage sector development projects (Table 4). The dependent variable is the winning and losing evaluated (not read-out) bids in constant 2005 U.S. dollar terms; 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 5 shows the summary statistics. The contract value varies from less than one million to 270 million U.S. dollars. Correspondingly, the physical specifications of contracted work also widely differ. The daily water treatment capacity could be 1,600 m^3 in some cases and 600,000 m^3 in others. The total length of erected pipes ranges from 0.1 km to 370 km, depending on contracts.

TABLE 4
Sample Coverage by Country

	Number of contracts	Number of bids
China	23	105
Croatia	4	20
India	5	11
Iran	6	38
Kazakhstan	1	2
Lebanon	2	2
Mexico	9	31
Morocco	1	6
Peru	4	16
Sri Lanka	1	2
Tanzania	4	12
Thailand	5	35
Viet Nam	1	3
Yemen	4	16
Total	70	299

TABLE 5
Summary Statistics

	Abb.	Obs.	Mean	Std. Dev.	Min.	Max
Bid amount (million US$)	*BID*	299	15.3	24.2	0.3	276.7
Number of bidders	*NUM*	70	5.3	3.3	2.0	16.0
Contract duration (month)	*MONT*	70	29.7	17.6	3.0	72.0
Dummy variable for water supply work	*DWAT*	70	0.46	0.50	0	1
Water treatment capacity (million m3)	*TRET*	29	0.18	0.17	0.001	0.600
Total length of iron pipes installed (km)	*PIPE*	49	60.5	77.6	0.1	375.6
Each bidder's total amount of backlogs in our sample (million US$)	*BKLG*	299	1.4	6.7	0.0	93.0
Country's received total sectoral ODA in the past 3 years (million US$)	*CAID*	70	302.6	346.6	2.7	888.7

ESTIMATION RESULTS AND IMPLICATIONS

First of all, the ordinary least squares (OLS) regression is performed (Table 6). Not surprisingly, it is evident that larger projects in terms of technical scope are more costly. The coefficients of *TRET* and *PIPE* are positive. However, the competition effect remains ambiguous in the OLS estimation; the coefficient of the number of bidders is positive but insignificant, which might be potentially biased because the number of bidders may be determined endogenously.

The IV estimator is supposed to address this endogeneity problem. The equilibrium bid has been found to decrease with the realized number of bidders. The coefficient of the number of bidders is estimated at –0.927 without quadratic terms and –0.661 with the quadratic expansion, respectively. Both are statistically significant. In addition, the Hausman exogeneity test, which is a standard comparison between two model coefficients, shows that the number of bidders is likely endogenous. The test statistics, which are distributed according to the chi-square distribution, are estimated at 21.57 and 12.83 for the models without and with a quadratic term. The critical value to a 95 percent significance level is $\chi^2(1)=3.84$. Therefore, the exogeneity hypothesis can be rejected strongly. On that account, it can be concluded that there is the significant competition effect in this procurement market; with more intense competition, the public infrastructure procurement could be lowered (see below for further discussion on the first stage regressions).

It is also found that the estimated IV bid function does not indicate any significant effect of economies of scope. The coefficient associate d with an interactive term of *TRET* and *PIPE* is estimated at 0.023 with a standard error of 0.015. It is statistically insignificant and positive, not negative. Hence, it is unlikely that a single contractor could undertake the two types of public work at cheaper costs than two companies would do separately. This can be interpreted to mean that the significant coordination cost might be required for the separate lots. It is worth iterating that the IV estimator control the endogeneity of bidder participation. As will be seen, our first regressions have captured the process by which bidders decide to enter or not to enter the market. Accordingly, this interactive term is supposed to represent the only direct impact of bundling the two components on the bidders' cost structure, exclusive of the indirect (anti)competitive effect of bidder entry via the number of bidders.

With the number of bidders replaced with the predicted number of bidders based on the zero truncated negative binomial model, the 2SLS regression results are found broadly consistent with the above IV estimates. The technically larger, the more costly. The bid would decrease with the number of bidders. The cost function would likely exhibit diseconomies of scope between a treatment plant and distribution network component; the coefficient of the interactive term between *TRET* and *PIPE* is found significantly positive, indicating a clear risk of high procurement costs under the bundling strategy.

TABLE 6
OLS, IV and 2SLS Regression Results

	OLS	OLS	IV	IV	2SLS w/ negative binomial	2SLS w/ negative binomial
ln*NUM*	0.139	0.130	–0.927***	–0.661**	–0.167	–0.538***
	(0.089)	(0.080)	(0.267)	(0.286)	(0.137)	(0.199)
DWAT	–0.415***	–0.344**	–0.123	–0.329**	–0.356***	–0.431***
	(0.149)	(0.142)	(0.160)	(0.148)	(0.138)	(0.136)
ln*TRET*	0.050***	0.943***	0.048***	1.205***	0.049***	1.158***
	(0.016)	(0.242)	(0.016)	(0.281)	(0.015)	(0.249)
ln*PIPE*	0.019	0.336**	–0.006	0.306	0.014	0.314*
	(0.015)	(0.172)	(0.015)	(0.193)	(0.015)	(0.180)
(1/2)ln*TRET**ln*TRET*		0.098***		0.127***		0.121***
		(0.028)		(0.033)		(0.029)
ln*TRET** ln*PIPE*		0.019		0.023		0.023*
		(0.013)		(0.015)		(0.014)
(1/2)ln*PIPE**ln*PIPE*		0.034*		0.028		0.028
		(0.020)		(0.023)		(0.021)
ln*MONT*	0.820***	0.954***	0.607***	0.864***	0.761***	0.882***

	(0.116)	(0.131)	(0.160)	(0.192)	(0.114)	(0.147)
Constant	13.93***	15.04***	17.06***	17.97***	14.82***	17.49***
	(0.46)	(0.58)	(0.84)	(1.21)	(0.50)	(0.86)
Obs.	299	299	299	299	299	299
R-squared	0.839	0.868	0.713	0.811	0.8377	0.871
F-statistics	598.2	1126.5	361.9	353.0	562.9	3723.0
Number of dummies:						
Donor	1	1	1	1	1	1
Country	11	11	11	11	11	11
Bidder nationality	19	19	19	19	19	19

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

The winning bid regression is largely consistent with the above estimation results (Table 7). Obviously, some of the coefficients turned out statistically less significant, because of the smaller number of observations. However, regardless of specifications, the interactive term of *TRET* and *PIPE* has a positive and significant coefficient, suggesting that there are no cost complementarities between these two public works. Rather, the cost would increase when bundling them. It is also indicated that competition is an important factor to contain public procurement costs; the coefficient associated with the number of bidders is found negative in the IV and 2SLS estimators, though statistically less significant in some specifications.

The two-stage quantile regressions (2SQR) seem to have captured the stronger competition effect in the higher tail (Table 8). As discussed by Li and Perrigne (2003), the bid strategy may be potentially different across bid levels. In our case, it is shown that the competition effect is more powerful in auctions when submitted bids are larger. This is considered reasonable, given that competition is in fact much limited in the high end and therefore the marginal effect of competition would likely be large. The 2SQR also reveals that diseconomies of scope between the treatment plant and network components would be especially significant when the individual contract amounts are small. This may mean that, for relatively small public contracts a number of small local enterprises would apply. However, they are often specialized companies and cannot undertake more than one task. Therefore, the bundling strategy will cost more especially for those small contractors. In addition, significant diseconomies of scope are also observed for extremely large contracts. Notably, the 90 percentile of bids exceeds 27 million U.S. dollars. In this range, the bundling strategy may also be inappropriate, simply because the contract amount is already significant and each of the works may require considerable resources and highly specialized skills. As a result, bundling might add more to large contracts.

As discussed, the above small value translog estimators can cause bias when too many observations take zeros for *TRET* and *PIPE*. Under the Composite specification where the values are directly used in the estimation, the equilibrium bid function is re-estimated. The results are shown in Table 9 and found consistent with the above. The competition effect tends to be pro-competitive; the more competition, the lower procurement costs. The bundled procurement is not pro-competitive; the bids are likely to be elevated given a bundled package. This anticompetitive effect of bundling is especially evident in the Composite specification.

TABLE 7
Winning Bid Regressions

	OLS	OLS	IV	IV	2SLS w/ negative binomial	2SLS w/ negative binomial
ln*NUM*	0.019	0.138	–1.397**	–0.809	–0.419*	–0.247
	(0.171)	(0.152)	(0.649)	(0.860)	(0.230)	(0.297)
DWAT	–0.478*	–0.436*	–0.289	–0.449	–0.429*	–0.459*
	(0.258)	(0.264)	(0.390)	(0.287)	(0.241)	(0.249)
ln*TRET*	0.032	0.742***	–0.003	0.860***	0.024	0.791***
	(0.028)	(0.186)	(0.034)	(0.282)	(0.025)	(0.197)
ln*PIPE*	0.013	0.312***	–0.024	0.203	0.002	0.262**
	(0.027)	(0.093)	(0.028)	(0.159)	(0.025)	(0.103)
(1/2)ln*TRET**ln*TRET*		0.079***		0.094***		0.085***
		(0.020)		(0.032)		(0.022)
ln*TRET** ln*PIPE*		0.017**		0.016*		0.017**
		(0.008)		(0.010)		(0.008)
(1/2)ln*PIPE**ln*PIPE*		0.035***		0.020		0.028**
		(0.012)		(0.022)		(0.014)
ln*MONT*	1.008***	1.012***	0.659	0.705	0.894***	0.880***
	(0.279)	(0.276)	(0.545)	(0.537)	(0.269)	(0.319)
Constant	13.40***	14.01***	17.24***	17.44***	14.65***	15.47***
	(0.99)	(1.20)	(2.31)	(3.57)	(1.07)	1.64
Obs.	70	70	70	70	70	70
R-squared	0.845	0.863	0.634	0.814	0.853	0.893
F-statistics	130.1	11283.9	52.0	63.3	33667.2	137.0
Number of dummies:						
Donor	1	1	1	1	1	1
Country	6	6	6	6	6	6
Bidder nationality	8	8	8	8	8	8

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

TABLE 8
Two-Stage Quantile Regression Results

	Quantile				
	0.1	0.25	0.5	0.75	0.9
ln*NUM*	–0.561	–0.256	–0.482***	–0.425*	–1.095***
	(0.387)	(0.700)	(0.062)	(0.238)	(0.390)
DWAT	–0.324*	–0.310	–0.188***	–0.215	–0.589
	(0.187)	(0.397)	(0.039)	(0.196)	(0.424)
ln*TRET*	1.514***	1.231**	0.668***	0.696***	1.536***
	(0.207)	(0.507)	(0.052)	(0.232)	(0.487)
ln*PIPE*	0.212***	0.452*	0.048*	0.151	0.490*
	(0.069)	(0.240)	(0.029)	(0.116)	(0.287)
(1/2)ln*TRET**ln*TRET*	0.160***	0.131**	0.065***	0.069***	0.167***
	(0.022)	(0.056)	(0.006)	(0.026)	(0.054)
ln*TRET**ln*PIPE*	0.019***	0.031*	0.001	0.006	0.046**
	(0.004)	(0.018)	(0.002)	(0.008)	(0.020)
(1/2)ln*PIPE**ln*PIPE*	0.014*	0.047*	–0.001	0.012	0.044
	(0.008)	(0.027)	(0.003)	(0.013)	(0.030)
ln*MONT*	0.511***	0.691*	0.856***	1.057***	1.023***
	(0.204)	(0.391)	(0.034)	(0.117)	(0.261)
Constant	19.481***	17.108***	16.726***	15.916***	19.220***
	(1.273)	(2.810)	(0.262)	(0.930)	(1.472)
Obs.	299	299	299	299	299
Pseudo R-squared	0.745	0.663	0.661	0.647	0.657
Number of dummies:					
Donor	1	1	1	1	1
Country	11	11	11	11	11
Bidder nationality 1/	19	11	15	12	12

1/ Some of the dummy variables are omitted due to multicolinearity.
Note: The dependent variable is the log of the bid amount. The standard errors are shown in parentheses. *, ** and *** indicate the 10%, 5% and 1% significance levels, respectively.

TABLE 9
OLS, IV and 2SLS Regression Results: Composite Specification

	OLS	OLS	IV	IV	2SLS w/ negative binomial	2SLS w/ negative binomial
ln*NUM*	0.066	0.089	–0.322	–0.809***	–0.434***	–0.763***
	(0.084)	(0.080)	(0.316)	(0.271)	(0.158)	(0.249)
DWAT	–0.285**	–0.289*	–0.198	–0.154	–0.198	–0.270**
	(0.133)	(0.150)	(0.140)	(0.146)	(0.134)	(0.132)
TRET	1.845***	2.703***	2.237***	2.692***	2.265***	0.694
	(0.284)	(0.785)	(0.406)	(0.931)	(0.345)	(1.044)
PIPE 1/	1.162*	3.376*	0.501	–0.804	0.159	–1.959
	(0.694)	(1.766)	(0.952)	(2.582)	(0.731)	(2.425)
(1/2)*TRET*TRET*		–2.630		–0.031		5.758*
		(1.977)		(2.908)		(3.455)
*TRET*PIPE*		0.766***		0.698***		0.757***
		(0.123)		(0.144)		(0.123)
(1/2)*PIPE*PIPE* 1/		–0.006		0.011		0.015
		(0.010)		(0.013)		(0.012)
ln*MONT*	0.842***	0.872***	0.817***	0.826***	0.854***	0.800***
	(0.102)	(0.098)	(0.122)	(0.150)	(0.106)	(0.108)
Constant	13.27***	13.06***	14.25***	15.38***	14.41***	15.39***
	(0.43)	(0.41)	(0.93)	(0.87)	(0.43)	(0.76)
Obs.	299	299	299	299	299	299
R-squared	0.850	0.863	0.843	0.781	0.853	0.866
F-statistics	36714.6	1.9E+07	6714.8	1.0E+06	35506.5	4.6E+12
Number of dummies:						
Donor	1	1	1	1	1	1
Country	11	11	11	11	11	11
Bidder nationality	19	19	19	19	19	19

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

Finally, the first stage regressions reveal several important findings about how firms decide whether or not to participate in competitive bidding. As shown in Table 10, our instrumentation is not weak. The first two column models in the table are associated with the last column 2SLS models in Table 6 and Table 9, respectively. The third and fourth column models are the first stage linear regressions for the expanded IV models in Tables 6 and 9, respectively.[17] Large-scale water projects, especially in terms of the length of installed transmission and distribution pipes, are less attractive for potential contractors, possibly because of their labor intensity and lengthy contract period. In fact, the coefficient of *MONT* is supportive of the fact that fewer bidders would participate for projects lasting a longer period. There is an indication that the bundling strategy would likely reduce bidder participation. In the composite or non-log specification, the coefficient of the interactive term between *TRET* and *PIPE* is found negative, and it is statistically significant in the first stage regression for the IV estimation. This appears compatible with the distributional dominance of single task contracts in Figure 1. As discussed, the cost structure does not seem to exhibit economies of scope, and worse, the bundling might have an entry deterrence effect, pushing up the public procurement cost further. All the indications are that the bundled procurement is not optimal in this specific case.

Evidence also indicates that the implementation capacity of private businesses is essential to promote bidder participation. The coefficient of *CAID* is found consistently positive, meaning that more contractors would likely apply for public contracts when a large amount of similar development projects were implemented in the past. The coefficient of *BKLG* is also positive, though statistically insignificant. This can be interpreted as the fact that the bidder qualification process in infrastructure procurement would place strong emphasis on the bidders' past experiences as an important proxy of their efficiency and responsiveness. Therefore, more contractors could enter the market, as they accumulate more experiences.

TABLE 10
Truncated Negative Binomial and Log-Linear Regressions on Number of Bidders

	Zero truncated negative binomial		1st stage regression for IV	
	Log	Non-log	Log	Non-log
ln*BKLG*			0.002	0.003
			(0.002)	(0.003)
ln*CAID*	0.451***	0.308**	0.343***	0.270***
	(0.136)	(0.136)	(0.069)	(0.073)
DWAT	0.068	0.183	0.217**	0.326***
	(0.201)	(0.218)	(0.097)	(0.101)
ln*TRET* 1/	0.307	–2.067	0.319***	0.550
	(0.219)	(1.741)	(0.119)	(0.629)
ln*PIPE* 1/	–0.099	–0.007**	–0.093	–0.005***
	(0.098)	(0.003)	(0.069)	(0.001)
(1/2)ln*TRET**ln*TRET* 1/	0.036	9.003*	0.037***	1.235

	(0.024)	(5.298)	(0.013)	(1.918)
ln*TRET**ln*PIPE* 1/	0.001	–0.284	0.001	–0.335**
	(0.007)	(0.191)	(0.005)	(0.150)
(1/2)ln*PIPE**ln*PIPE* 1/ 2/	–13.607	0.030*	–11.813	0.024***
	(10.583)	(0.016)	(7.689)	(0.008)
ln*MONT*	–0.186	–0.157	–0.171**	–0.108
	(0.192)	(0.192)	(0.077)	(0.082)
Constant	0.109	1.954***	2.353***	1.784***
	(0.906)	(0.458)	(0.459)	(0.410)
Obs.	70	70	299	299
R-squared			0.729	0.690
F-statistics			17.35	14.32
Wald chi2	1.2E+05	5.0E+10		
Number of dummies:				
Donor	1	1	1	1
Country	12	12	11	11
Bidder nationality	0	0	19	19

1/ Not logarithmic for the non-log specifications.

2/ Multiplied by 1,000 for presentation purposes.

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

CONCLUSION

Competition has been largely limited in procurement auctions for infrastructure projects. The water supply and sanitation sector is not exceptional. It may be 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. The paper examines the tradeoff relationship between the degree of competition in competitive bidding and the size of contracts. Larger works could benefit from economies of scale and scope, which are generally expected to be exhibited by large-scale infrastructure procurement. On the other hand, large contracts would undermine competition if potential bidders are constrained by technical skills and other resources.

With the data on public procurement for water and sewage projects in developing countries, it is shown that the bidder entry would likely be endogenous and affected by the (un)bundling strategy between potentially different types of contracts, such as water treatment plant and distribution network work. Evidence suggests that if these two activities are bundled in a single lot package, competition would likely be limited because there may be only a few firms that can undertake both tasks together. This adverse entry effect would in turn raise the equilibrium bid, thus pushing up public procurement costs of infrastructure. In addition, there is no evidence that the underlying bidder cost structure exhibit economies of scope between these activities. Rather, the cost may increase by bundling, especially for relatively small contracts. Therefore, there is no rationale for bundling a water treatment plant and network component in this specific case. The paper, of course, focuses on only one application; however, the same type of analysis should be called for to design an efficient public procurement system. It will help developing countries to save a lot of public resources and create additional fiscal space for infrastructure development.

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NOTES

1. 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.
2. 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.

3. 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 m^3 per day is about 58 U.S. dollars per m^3. However, it will cost 200 U.S. dollars per m^3 if the procured capacity is only 100,000 m^3 per day.

4. Bidders will enter until their expected profits are driven to the entry cost. At this level no more firms can expect nonnegative profits from new entry. The optimal number of bidders would be increased by reducing entry costs and raising the profit guaranteed for a bidder with the highest possible procurement cost.

5. In practice, there are a variety of procurement systems involving different features, such as national preferences and technical evaluation process, possibly depending on the (expected) contract amount. However, regardless of such discrepancies, the fundamental rule applied for ODA project procurement is the first-price sealed-bid format, exclusive of consultant procurement.

6. 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 exhibits common value characteristics, such as the winner's curse. It has been found that the bids would decrease with the number of bidders even if more flexible specifications are used, such as partially nonparametric estimation and Box-Cox transformation with respect to the number of bidders, n. In the former, which is a fully flexible form for the effect of the number of bidders, the coefficients associated with the dummy variables for each n have been found broadly decreasing as n increases (Estache and Iimi, 2008). With the latter specification applied for the two-stage least-squares model (see the following Sections), it has been found that the coefficient

of the number of bidders has still been found significantly negative at a Box-Cox transformation parameter of –1.46. The evidence indicates that the appropriate specification is either a natural log or a multiplicative inverse model.

7. A large number of enterprises are potentially interested in applying for a public contract but often gradually excluded from the selection process in due course. Some may decide not to enter the market because of their own financial and experiential constraints, and others may be disqualified by governments in the middle of the process (Estache and Iimi, 2009b). As a result, even though only one bid is submitted, the bidding process may be considered valid if prices are reasonable in comparison to market values given the conditions of contract, design and specifications, scope of the contract. See, for instance, the World Bank's *Guidelines Procurement under IBRD Loans and IDA Credits*, Clause 2.61. The number of prequalified bidders is usually common knowledge prior to the bidding stage because the prequalification result is published. This is consistent with the underlying auction theory. However, not all qualifiers submit the bids. Hence, there is still room for endogeneity in bidder participation.

8. The figure reflects two distributions simultaneously to show the difference. The overlapping part is shown in a medium shade of gray.

9. From the auctioneer's point of view, in addition, it may be administratively much costly to procure a project under smaller contracts. A study indicates that fragmented low-value public contracts seem to have incurred a significant amount of managerial costs and a risk of severe coordination failure in Caribbean countries. The National Water Commission in the Caribbean had contracts with more than 34,000 suppliers and most of the contracts were for low-value invoices (World Bank, 2008b). Though, this does not affect our analysis because we focus on the bidders' behavior.

10. But the World Bank's *Guidelines Procurement under IBRD Loans and IDA Credits* do not allow mandatory joint ventures or other forms of mandatory association between firms.

11. See, for instance, the World Bank's *Guidelines Procurement under IBRD Loans and IDA Credits,* Clause 2.49.

12. 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 $i = 1, \cdots, n$. 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.

13. Infrastructure projects, especially in the water supply and sanitation sector, are very different from contract to contract. It is difficult, though not impossible, to collect all the data items from the bill of quantities in a consistent manner, while preserving the degrees of freedom in estimation. After a series of regressions, we have selected two major output measures, *TRET* and *PIPE*, and other two minor observables (*DWAT* and *MONT*).

14. There are several alternative instruments. For instance, the number of qualified bidders can be instrumented by the number of firms who applied for prequalification. The idea behind this is the same as the use of the number of plan holders in De Silva, Dunne, Knkanamge & Kosmopoulou (2008). The number of prequalification applicants is the maximum number of contenders that could participate in each auction. Applicants may not be quailed and can decide not to participate even if quailed. In our data, this information is limited and reduces our sample to 180 bids. But the main results have been found unchanged, even if this variable is introduced as an additional instrument. Not surprisingly, the number of prequalification applicants is positively correlated with the number of qualified bidders, which is used for *NUM* in the paper. The other possibility is to include governance indices as instruments. Early evidence shows that good governance would likely enhance bidder participation (e.g., Villegas, Morales & Andersson, 1998; World Bank, 2008a). When six indicators of governance are borrowed from the Worldwide Governance Research Indicators (Kaufmann, Kraay & Mastruzzi, 2008), government effectiveness and anticorruption policy have been found of particular importance to encourage bidder participation. But the estimated bid functions have not differed in other aspects from the main results presented in the paper.

15. In constant 2005 U.S. dollar terms.
16. *CAID* is supposed to complement *BKLG* in the sense that our sample covers only a fraction of the official infrastructure development projects.
17. The first stage regression results for other specifications are omitted since they are more or less the same as the estimates shown in Table 10.

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