Policy Research Working Paper 4459

(UN)Bundling Public-Private Partnership Contracts in The Water Sector:

Competition in Auctions and Economies of Scale in Operation

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January 2008

Abstract

In public-private partnership transactions in the water sector, one of the alleged concerns is that there is little market competition at the auction stage. This paper casts light on a tradeoff between the competition effect at the auction level and potential economies of scale in service operation. If the authorities design a large-scale public-private partnership water transaction, it is expected to exploit operational scale economies. But the competition effect may have to be sacrificed. The paper shows a risk that the selection of the contract size could be a very restrictive condition that excludes many prospective bidders. Moreover, the paper quantifies the optimal size of public-private partnership contracts in the sector by estimating a cost function. The analysis shows that economies of scale exist but tend to diminish quickly as production increases. When the amount of water sold exceeds about 40 million m^3, the statistical significance of economies of scale disappears. And there is no rationale for auctioning the water operation with annual water delivery of more than 400 million m^3 under a single contract.

This paper—a product of the Finance, Economics and Urban Development Department—is part of a larger effort in the department to examine how to improve efficiency of public-private partnership contracts in the water supply sector. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The author may be contacted at aiimi@worldbank.org.

(UN)BUNDLING PUBLIC-PRIVATE PARTNERSHIP CONTRACTS IN THE WATER SECTOR:

COMPETITION IN AUCTIONS AND ECONOMIES OF SCALE IN OPERATION

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[¶] The paper greatly benefits from the database which has been developed through funding from the Public-Private Infrastructure Advisory Facility (PPIAF). I am most grateful to my colleagues, Katharina Gassner and Nataliya Pushak, for their efforts toward collecting the relevant data which are used in the paper. I also thank Antonio Estache, Laszlo Lovei, Nataliya Pushak for their insightful comments on an earlier version of this paper.

I. INTRODUCTION

Following a large buoyancy in public-private partnership (PPP) transactions in the telecommunications and electricity industries, some water supply and sewerage services are also provided under the PPP framework. However, there has been a mixed picture of the water-sector PPP performance. Some experiences are praised, and others are not. The failure is partly attributable to design flaws in their auction mechanisms. One of the alleged concerns is that there is little market competition at the auction stage. It is not unusual that a PPP transaction in the water sector has no competition even under competitive bidding circumstances.

In designing an auction for PPP infrastructure transactions, one of the most important policy decisions for the auctioneer is whether to bundle or unbundle potentially relevant transactions for optimizing the size of contracts. The current paper examines the possibilities of improving efficiency in water-sector PPP auctions and discusses whether or not the current choice of contract size is appropriate. There are two factors that potentially determine the optimal contract size: competition in the auctions and economies of scale in operation. The two factors may or may not be compatible with one another. Dividing a project into small contracts may look like an attractive approach for the auctioneer, because it will encourage more prospective firms to participate in the auction process. At the same time, however, the possible benefits from economies of scale and scope, which infrastructure construction, operation and maintenance usually exhibit, may have to be sacrificed.

In general, the degree of competition at the PPP-related auctions tends to be low. Particularly in water-sector transactions, competition has been minimal (e.g., Foster, 2005). As per the Private Participation in Infrastructure Project Database (hereinafter referred to as PPI Database), the average number of firms that participate in a PPP auction ranges from three to six, depending on sector. In the water and sewerage sector, the average is about 3.6, which is unfavorable compared with other infrastructure sectors. Of particular note, in the Latin America and the Caribbean (LAC) region, the average number of participants in each water-sector PPP auction is merely 2.2. Many water concessions in LAC were auctioned with one or two firms involved.

From the competition point of view, auction theory suggests that the decision on whether to bundle or unbundle a set of relevant objects is essential for auctioneers to enhance competition and thus achieve high efficiency. Under multiple-unit auction circumstances, Palfrey (1983) shows that if there are only a few bidders for an arbitrary number of objects, the auctioneer should bundle all the objects to facilitate competition among them. By contrast, with a relatively large number of bidders the auctioneer may prefer to unbundle the objects. As per Chakraborty (2006), the entry cost is considered a key policy parameter to decide whether to bundle. It is shown that if the entry cost is sufficiently large, separate auctions become more preferable for the auctioneer as the cost increases. Moreover, if the auctioneer can choose the level of entry cost at the optimal level, separate auctions are always be superior to the bundle auction, regardless of the entry cost.

The above (auction) competition argument may ignore the importance of possible affiliation among the values of the auctioned objects. From the practical point of view, a crucial determinant of the optimal contract size of PPP transactions is the extent to which the industry could exploit economies of scale at the operational stage. A water utility is still typically characterized as a network overlaid upon a spatial distribution of supply and demand, which could generate economies of scale (Clark and Stevie, 1981).[1] Garcia and Thomas (2001), estimating the cost structure of municipal water utilities in France, find significant economies of scale on average but considerable diseconomies of scale when the volume of delivered water is greater than 165 m^3 per customer. Positive economies of scale can be interpreted to mean that local water services may benefit from merging into water districts. Kim and Lee (1998) also find significant economies of scale in water service

[1] There is a tradeoff between the cost of establishing facilities and the cost of transporting products/services in the network industry. Higher facility costs and lower transport costs would result in the centralized system. But lower facility costs and higher transport costs are associated with the decentralized one. Clark and Stevie (1981) find the optimal utility size.

provision for the Seoul metropolitan area. Nauges and van den Berg (2007) confirm the existence of total economies of scale for any size of utility operation in the cases of Brazil, Colombia, Moldova and Vietnam.[2]

By estimating the cost structure, this paper aims to infer the significance of scale economies in PPP operations of water systems in developing countries. Based on global experience, at the same time, it also provides evidence that the decision as to the contract size would tend to have strong power to restrict competition in the water sector.

The tradeoff between the competition effect and scale economies seems to have been a traditional challenge for auctioneers in designing PPP-related auctions. In the 1993 Buenos Aires water concession case, for instance, the number of prospective bidders was expected to be small when all of Buenos Aires with 8.7 million of population (at that time) was contracted out in a single 30-year contract, which was among the largest ever bidding competitions in developing countries. However, a significant technical disadvantage of splitting the system to two regions was considered more problematic. There was also a political concern about the unprofitable suburban area when taking the unbundling strategy. As a result, a single concession was selected. Five consortia were prequalified, and only three of them actually bid on the transaction—and renegotiation occurred in 1997 (Alcázar *et al*., 2002).

By contrast, in the case of Mexico City's water service management, the government decided to contact out various operations to four zonal contractors. At time of the auction in 1993, the city population amounted to 8.4 million. Seven consortia participated in the bidding process, and four operators were awarded for four zones comprising 16 *delegaciones* (Haggarty *et al*, 2002).

[2] In their argument, total economies of scale are referred to as returns to production density to distinguish from returns to scale, which take into account population increases and network expansion.

Notably, even in a small PPP water transaction, competition may also be limited. In the Conakry water lease contract concluded in 1989, six international water companies expressed interest, and only two consortia, which were composed of four initial applicants, submitted their bids. At that time, the city's population amounted to about one million. However, the water system coverage was exceptionally low at less than 40 percent (Ménard and Clarke, 2002). Hence, along with the competition and scale issues, other factors must affect the optimality of the contract size. In the Conakry case, both diseconomies of scale and diseconomies of customer density seem to have mattered.

In the existing literature, there are few studies addressing a question about how to decide the optimal size of the PPP contracts. Under what circumstances should the auctioneers downscale or upscale the contract size in order to attract more potential bidders? The paper aims at providing certain qualitative answers to those questions.

The following section is organized as follows. Section II provides an overview of the degree of competition in the water-sector PPP transactions, using the two comprehensive databases on PPP transactions in the world. Section III estimates a cost structure of water and sewage service operations where the private sector is partially or fully involved. Finally, Section IV discusses some tentative policy implications for designing efficient PPP auctions in the water sector.

II. Overview of Competition in PPP Transactions for Water Services

Regardless the way in which the private sector is involved—i.e., traditional construction procurement or more comprehensive PPP contracts—the degree of competition generally tends to be low in the infrastructure industry. There are a very small number of active players in each infrastructure sub-sector, presumably because of the significant complexity and value involved in the infrastructure provision.

In the 3G mobile telecommunications experiences in European countries, for instance, the number of bidding firms per license ranges from 0.75 to 2.6. In the United Kingdom, five licenses were auctioned among 13 bidders. On the other hand, there was no competition in the Austrian and Swiss cases, meaning that the number of bidders was eventually the same as the number of licenses to be issued (Klemperer, 2002; van Damme, 2002). NOA (2007) indicates that half of the past U.K. PFI projects attracted at most two or three bids. Similarly, in the railway concession cases in Argentina and Brazil during the 1990s, two to four firms participated in the bidding process. Particularly, the freight train contracts, which may be less profitable from the private sector point of view, attracted only one or two bidders.

How many bidders are required for sufficient competition? Gupta (2002) shows that the highway construction market (in Florida) becomes competitive with about six to eight bidders.[3] As per Iimi (2006), large-scale official development projects—mostly in the infrastructure sector—require eight firms to minimize the contract prices. In the U.S. offshore oil lease market, a similar level of bidder participation seems necessary for competition purposes (Brannman *et al*., 1987).

Developing countries may have an even more limited competition in PPP infrastructure auctions. The PPI Database shows that about 60 percent of PPP infrastructure transactions in developing countries involved one to three bidders (Figure 1).[4] About 15 percent of contracts attracted only one bidder even under the competitive bidding circumstances. The degree of competition varies depending on sector. It is the lowest at 3.6 in the water sector. By contrast, the telecommunications and road sectors could attract more participants on average, as expected.

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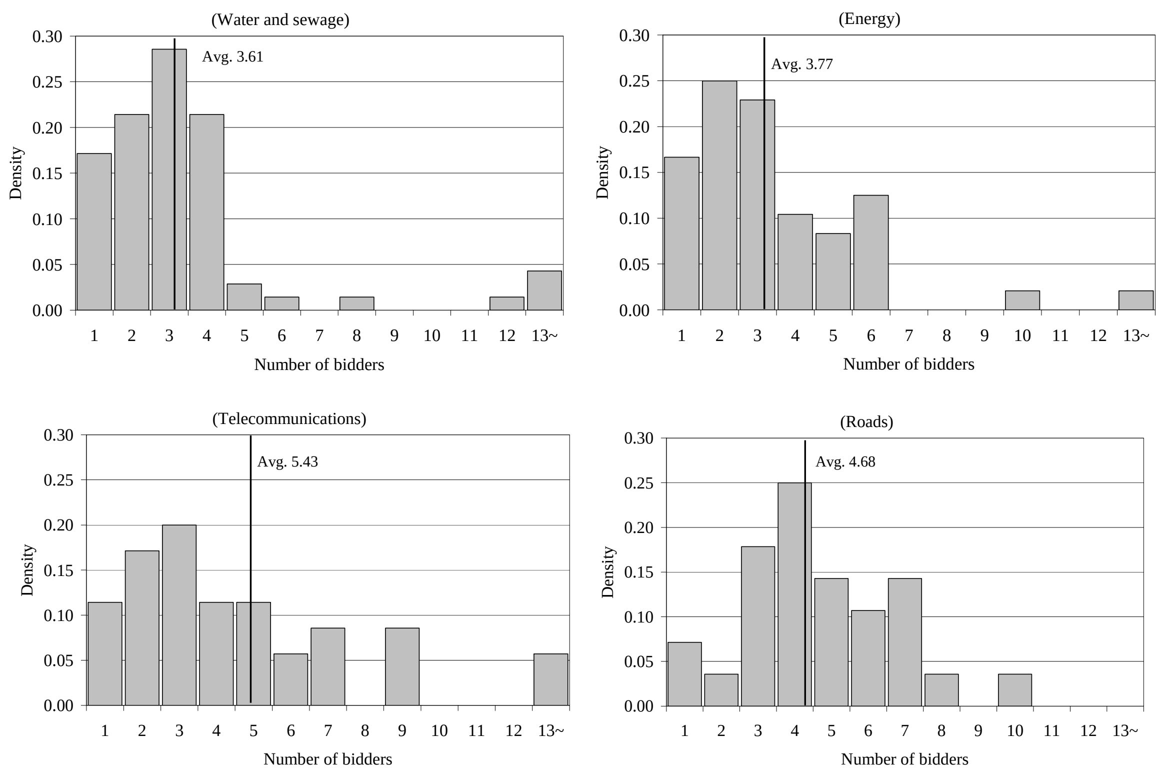
[3] It means that the marginal impact of one more bidder on the equilibrium bid is not statistically significant when the number of participants exceeds eight.

[4] The database covers only transactions of which total investment commitments exceed US$ 1 million.

Figure 1. Number of Bidders in PPP Auctions by Sector

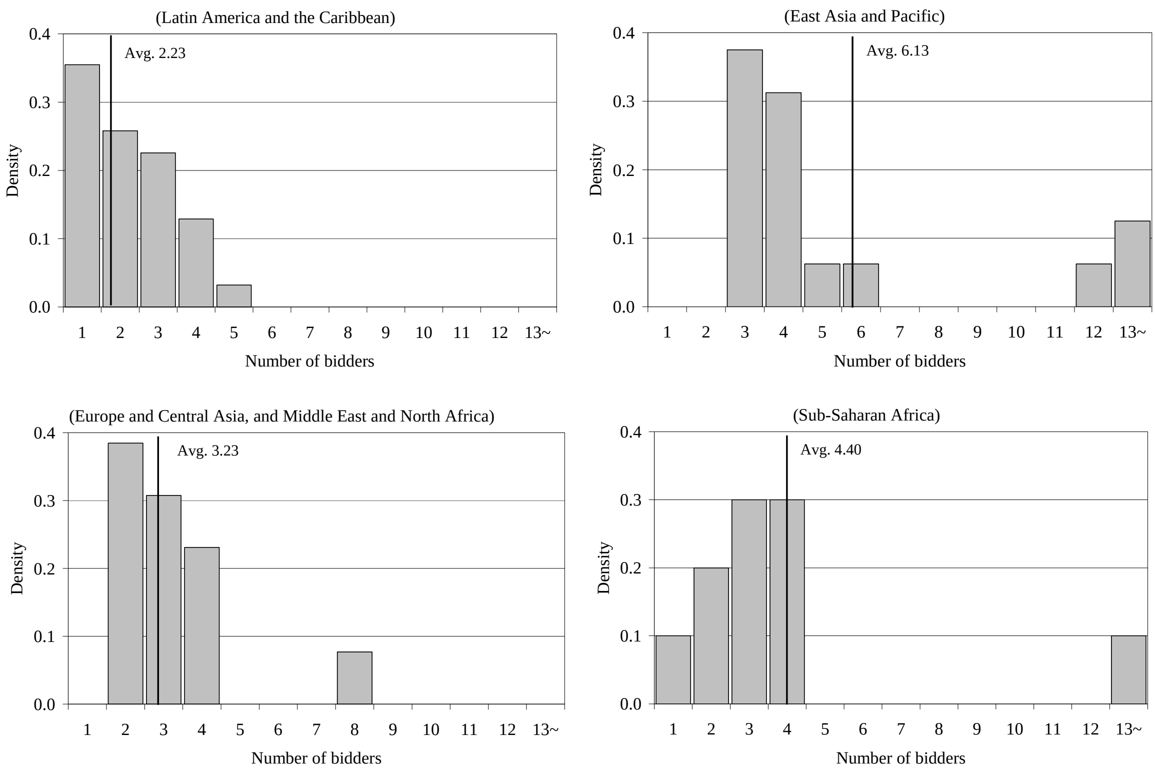


Source: PPI Database.

A natural question is why auction-based competition is so limited in the water sector. Foster (2005) mentions that many water concession auctions in the Latin American in the 1990s involved one to three bidders. More importantly, it is indicated that market concentration seems high; three large international water service operators—i.e., SUEZ (former Lyonnaise des Eaux), Aguas de Barcelona, and Veolia Environnement (former Vivendi Environnement)—regularly participated in the PPP auctions. Hence, it seems that only a few firms are able to undertake PPP water transactions or compete with those incumbents.

The Latin America and the Caribbean (LAC) region is in fact faced with a particularly serious problem with lack of competition in the water service transactions (Figure 2). The LAC countries, on average, involved only two firms in their competitive selection process. Moreover, the density distribution of the number of bidders per auction is heavily distributed on the left side; the majority of PPP water transactions have no competition. This phenomenon is characteristic of the LAC region.

Figure 2. Number of Bidders in Water-Sector PPP Auctions by Region



Source: PPI Database.

"Overspecification" is one of the alleged reasons for the limited competition in water-sector PPP transactions. In general, infrastructure construction and its operation and maintenance require a considerable amount of technical, experiential and managerial resources. On top of that, there are a few active players in the private water sector, as mentioned above. As a result, there is always a great risk that too restrictive qualification conditions could easily exclude most of potential firms that might be interested in bidding on the transactions.

The Private Participation in Infrastructure Services (PPIS) Database, which covers most private and public water utilities over the world, reveals that the past PPP transactions in the water and sewerage sector seem to have been relatively small (Figure 3). For example, about 90 percent of water contracts aim to deal with utilities producing—more precisely selling—

less than 100 million cubic meters of water per annum. Note that the figure excludes several outliers (i.e., extremely large observations) for illustration purposes. The figure clearly shows that if the authorities attempt to contract out the water service operation selling more than 100 million cubic meters of water, firms that had such operational experiences would be very limited even over the world. Similarly, there are few transactions to collect sewage water of more than 50 million cubic meters.

Accordingly, there is a clear tradeoff between the competition effect at the auction level and potential economies of scale in service operation. If the authorities give priority to the operational scale effect and design a large-scale PPP water transaction, the competition effect would be likely limited because of the small number of firms that are allowed to participate in the competitive bidding. This is exactly what happened in the case of the 1993 Buenos Aires water concession auction. On the other hand, if the authorities choose to unbundle the transaction to several small contracts, a greater number of bidders can be expected to participate in the bidding process, possibly resulting in higher economic efficiency.

The practical optimality of the contract size must depend on the extent to which the PPP water service operation exhibits economies of scale. This is examined in the following section.

Another interesting finding from Figure 3 is that the distribution of the number of employees appears less skew.[5] This may be able to be interpreted to mean that the water-sector PPP has a potential structural problem of over-employment, whence low labor productivity. Particularly, small-scale service operations seem to necessitate relatively more employees. This may merely reflect the existence of economies of scale of operation with respect to labor input, but it could be an indication of excess employment.

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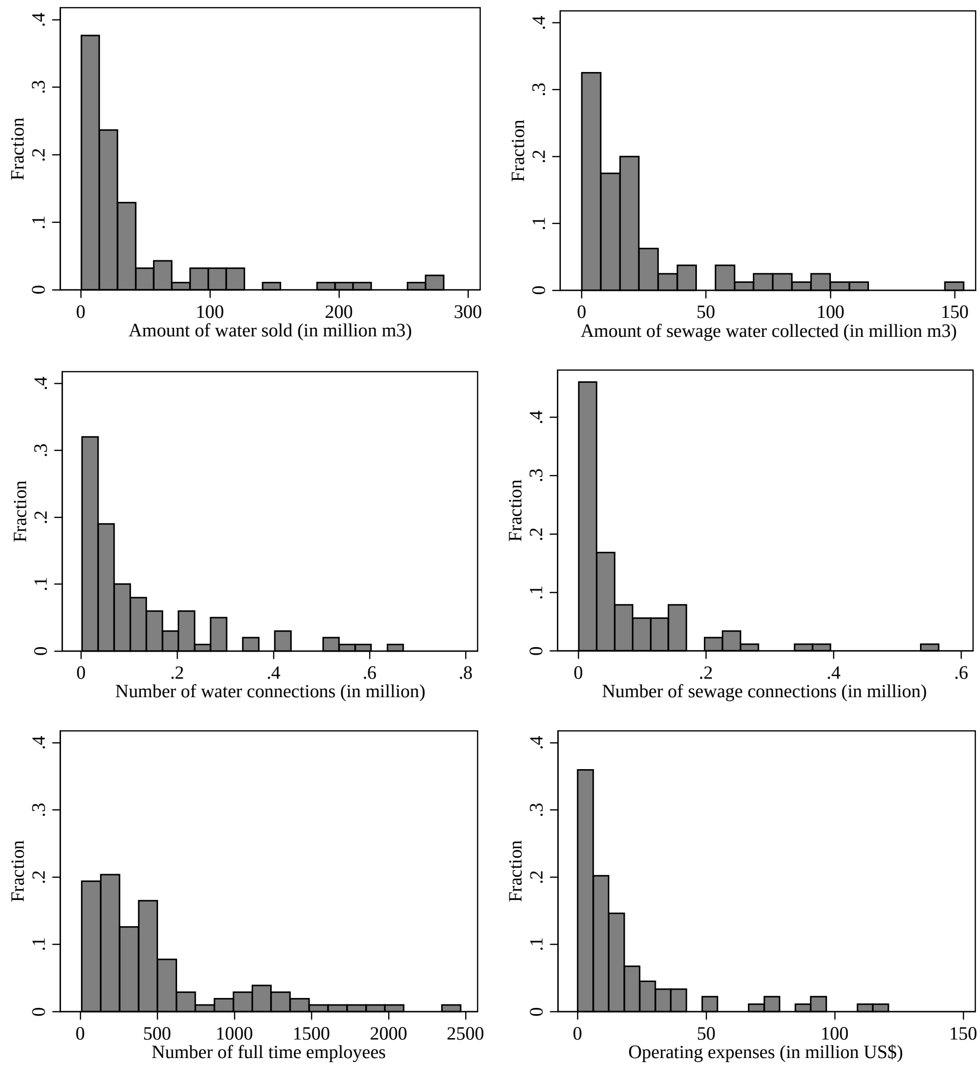
[5] The data are not pooled but cross-sectional, taking the average when a utility has more than one observation after its private sector involvement.

Figure 3. Density Distribution of Size of Water-Sector PPP Contracts in the World



Source: PPIS Database.

III. Estimating Economies of Scale in PPP Water Operations

Empirical model

Based on the traditional industrial organization literature (e.g., Nerlove, 1963; Christensen and Greene, 1976), the following cost function is estimated by a seemingly unrelated regression (SUR) technique:

$$
\begin{aligned}
\ln C = {} & \beta_0 + \sum_i \beta_{Y_i} \ln Y_i + \frac{1}{2}\sum_i \sum_j \beta_{Y_iY_j} \ln Y_i \ln Y_j + \sum_k \beta_{W_k} \ln W_k \\
& + \frac{1}{2}\sum_k \sum_l \beta_{W_kW_l} \ln W_k \ln W_l + \sum_i \sum_k \beta_{Y_iW_k} \ln Y_i \ln W_k \\
& + \sum_m \beta_{Z_m} \ln Z_m + \frac{1}{2}\sum_m \sum_n \beta_{Z_mZ_n} \ln Z_m \ln Z_n + \sum_i \sum_m \beta_{Y_iZ_m} \ln Y_i \ln Z_m \\
& + \sum_k \sum_m \beta_{W_kZ_m} \ln W_k \ln Z_m + \varepsilon
\end{aligned} \tag{1}
$$

where C denotes total operating costs, Y_i is ith output, and W_k is kth input price. Z_m represents an exogenous technical variable, such as the network size, to control for heterogeneity among utilities.

Following Garcia and Thomas (2001) and García-Valiñas and Muñiz (2007), two output variables are adopted: the amount of water sold and the amount of sewage water collected. These are denoted by Y_w and Y_s, respectively. Our database covers both water and sewerage utilities. Naturally, some water utilities are providing sewerage services as well. If an operator supplies either water or sewerage service, the nonoperational output measure is set at a very small positive number, but not zero.

Two inputs are conceptually considered: labor and other operation and maintenance (O&M) materials. Unit labor price W_L is obtained by dividing total wage expenses by total number of employees (in both water and sewerage operations). On the other hand, O&M material expenses potentially consist of various costs, and the unit price of input materials (W_M) is computed by dividing the operating expenses other than wages by the sum of the two output variables. This is just for computational purposes.

Two technical characteristics are involved: the number of water connections denoted by Z_W, and the number of sewage connections, i.e., Z_S. These are supposed to capture the degree of economies of customer density. In the utility sector, it may be possible to increase service production with its network size unchanged, yielding higher profits. Even with some adjustments of capacity required, the total cost may not increase proportionally. This effect is often referred as to economies of customer density.

Given Equation (1), the following symmetry and homogeneity restrictions are imposed to have a well-behaved cost function:

$$\beta_{Y_iY_j} = \beta_{Y_jY_i}, \beta_{W_kW_l} = \beta_{W_lW_k}, \beta_{Z_mZ_n} = \beta_{Z_nZ_m},$$
$$\sum_k \beta_{W_k} = 1, \sum_k \sum_l \beta_{W_kW_l} = 0, \sum_i \sum_k \beta_{Y_iW_k} = 0, \sum_k \sum_m \beta_{W_kZ_m} = 0 \quad (2)$$

In addition, from Shephard's lemma, the following factor share equations are obtained:

$$S_k = \frac{\partial \ln C}{\partial \ln W_k} = \beta_{W_k} + \sum_l \beta_{W_kW_l} \ln W_l + \sum_i \beta_{Y_iW_k} \ln Y_i + \sum_m \beta_{W_kZ_m} \ln Z_m \quad (3)$$

where S_k is the cost share of input *k*. Through the SUR model, the cost parameters are estimated in Equation (1) and one of the factor share equations (3).[6] The advantage of the SUR is that higher efficiency in estimation could be expected without wasting the degree of freedom (Christensen and Greene, 1976).

Following the earlier literature (e.g., Baumol *et al*., 1982; Panzar and Willig, 1981; Rezvanian and Mehdian, 2002; Garcia and Thomas, 2001), the overall economies of scale in question can be computed by this:

$$SE = \frac{1}{\sum_i \eta_{Y_i}} \quad (4)$$

[6] One of the factor equations should be dropped to avoid the singularity problem.

where η_{Y_i} is the cost elasticity with respect to output *i*. The degree of economies of customer density is also calculated by:

$$ECD = \frac{1}{\sum_i \eta_{Y_i} + \sum_m \eta_{Z_m}} \qquad (5)$$

where η_{Z_m} is the cost elasticity with respect to the number of connections Z_m.

Data

All the data are employed from the Private Participation in Infrastructure Services (PPIS) Database, which provides the detailed operational information on most private and public water utilities since 1993. The current paper uses only observations under some types of PPP (affermage, management contract, lease, concession and divestiture). The cross-sectional time-series data are pooled; in most cases in our sample, each utility has 3–5 annual observations. Note that in the PPIS Database, the information on employment and wage expenses is not always provided separately for each of the water and sewage operations. In practice, the decomposition is sometimes infeasible when staffs are working on both operations.

Table 1 shows the summary statistics of costs, outputs, and factor prices. The sample observations are quite heterogeneous in any aspects, as indicated in Figure 3. For instance, annual operating expenses range from US$37,000 to more than US$ 100 million. The majority of observations are concession transactions.

Table 1. Summary Statistics

Symbol	Definition	Mean	Std. Dev.	Min	Max
C	Total annual operating expenses (US$)	16,127,980	24,862,140	37,032	167,203,400
Y_W	Amount of water sold (m3)	26,936,520	42,715,310	0	270,129,200
Y_S	Amount of sewage water collected (m3)	16,657,900	33,123,590	0	248,162,000
W_L	Unit labor cost (US$ per full time employee)	8,537	6,634	221	47,033
W_M	Unit operational material cost (US$ per sum of Y_w and Y_s)	0.310	0.207	0.011	1.482
Z_W	Number of water connections	79,344	103,904	0	585,953
Z_S	Number of sewerage connections	41,868	57,683	0	268,953
$Type_{(Affermage)}$	Dummy for affermage	0.023	0.150	0	1
$Type_{(Concession)}$	Dummy for concession transaction	0.716	0.452	0	1
$Type_{(Divestiture)}$	Dummy for divestiture	0.013	0.114	0	1
$Type_{(Lease)}$	Dummy for lease contracts	0.033	0.178	0	1
$Type_{(Management)}$	Dummy for management contracts	0.216	0.412	0	1

Estimation results

Equation (1) is first estimated simply by the Ordinary Least Squares (OLS) technique, and it is also estimated jointly with Equation (3) by the Seemingly Unrelated Regression (SUR) model. The estimated cost parameters are shown in Table 2. The signs of the coefficients are broadly consistent with theory. When the dummy variables for the PPP nature are included, the operating cost under management contracts and concessions are found significantly higher than the baseline (i.e., divestiture). This is merely the correlation but not causality; the possible selection bias is not controlled for.

Table 2. Estimated Cost Function of Water-Sector PPP Operation

	OLS				SUR			
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
β_{Yw}	0.3260	0.0223 ***	0.3388	0.0238 ***	0.3349	0.0197 ***	0.3502	0.0211 ***
β_{Ys}	0.1743	0.0135 ***	0.1728	0.0139 ***	0.1902	0.0103 ***	0.1945	0.0106 ***
β_{YwYw}	0.0412	0.0015 ***	0.0426	0.0017 ***	0.0438	0.0014 ***	0.0448	0.0016 ***
β_{YwYs}	-0.0046	0.0015 ***	-0.0042	0.0015 ***	-0.0052	0.0013 ***	-0.0049	0.0014 ***
β_{YsYs}	0.0147	0.0009 ***	0.0144	0.0010 ***	0.0149	0.0008 ***	0.0151	0.0009 ***
β_{WL}	-0.2411	0.1203 **	-0.2301	0.1235 *	-0.7480	0.0466 ***	-0.7522	0.0466 ***
β_{WLWL}	0.0981	0.0127 ***	0.0983	0.0133 ***	0.1121	0.0044 ***	0.1126	0.0044 ***
β_{WLWM}	-0.0952	0.0119 ***	-0.0943	0.0125 ***	-0.1025	0.0046 ***	-0.1022	0.0047 ***
β_{YwWL}	-0.0027	0.0015 *	-0.0026	0.0015 *	-0.0024	0.0009 ***	-0.0024	0.0009 ***
β_{YwWM}	0.0021	0.0018	0.0017	0.0018	0.0005	0.0012	0.0005	0.0012
β_{YsWL}	-0.0033	0.0010 ***	-0.0031	0.0011 ***	-0.0037	0.0004 ***	-0.0035	0.0004 ***
β_{Zw}	0.3512	0.1024 ***	0.3408	0.1056 ***	-0.1338	0.0328 ***	-0.1551	0.0351 ***
β_{Zs}	-0.0309	0.0175 *	-0.0364	0.0188 *	-0.0280	0.0152 *	-0.0444	0.0163 ***
β_{ZwZw}	0.0363	0.0083 ***	0.0406	0.0088 ***	0.0414	0.0077 ***	0.0469	0.0081 ***
β_{ZwZs}	0.0054	0.0045	0.0052	0.0046	0.0052	0.0040	0.0055	0.0041
β_{ZsZs}	-0.0044	0.0011 ***	-0.0038	0.0015 **	-0.0052	0.0010 ***	-0.0057	0.0013 ***
β_{YwZw}	-0.0142	0.0037 ***	-0.0169	0.0041 ***	-0.0165	0.0034 ***	-0.0193	0.0037 ***
β_{YwZs}	-0.0050	0.0035	-0.0043	0.0037	-0.0032	0.0031	-0.0022	0.0032
β_{YsZw}	-0.0042	0.0016 ***	-0.0049	0.0016 ***	-0.0047	0.0015 ***	-0.0056	0.0015 ***
β_{YsZs}	-0.0003	0.0001 **	-0.0003	0.0001 **	-0.0001	0.0001	-0.0001	0.0001
β_{WLZw}	-0.0482	0.0097 ***	-0.0491	0.0099 ***	-0.0046	0.0025 *	-0.0045	0.0025 *
β_{WLZs}	0.0046	0.0017 **	0.0046	0.0017 ***	0.0013	0.0007 *	0.0013	0.0007 *
β_{WMZw}	0.0462	0.0094 ***	0.0457	0.0096 ***	0.0042	0.0031	0.0023	0.0032
Type $_{(Affermage)}$			0.1803	0.1347			0.1014	0.1219
Type $_{(Concession)}$			0.1533	0.0890 *			0.1823	0.0815 **
Type $_{(Lease)}$			0.0564	0.1103			0.0557	0.1005
Type $_{(Management)}$			0.1679	0.0953 *			0.2206	0.0860 ***
Constant	4.3154	0.9540 ***	4.0391	0.9816 ***	8.8622	0.3047 ***	8.6990	0.3209 ***
No. of Obs.	306		306		306		306	
R-squared	0.9891		0.9893		0.9863		0.9865	
F-statistics	1110.78		947.62					
Chi square					31777.2		32735.3	

Note that *, * and *** denote the 10 percent, 5 percent and 1 percent significance levels, respectively. The divestiture case is used as a baseline.

The implied cost elasticity with respect to production is calculated in Table 3. They are all evaluated at the sample means. The cost elasticity of water production is much higher than that of sewerage treatment. A 1-percent increase in water production would raise the operating cost by 0.7 percent. On the other hand, a 1-percent increase in sewerage operation would result in only a 0.1 percent increase in costs. These elasticities seem to generate considerable economies of scale in this industry.

Indeed, the estimated overall scale effect, which is defined in Equation (4), implies that the water-sector PPP operation would be likely to exhibit economies of scale on average. When evaluating the scale effect at the sample means, the hypothesis that *SE* is less than unity can be easily rejected (Table 4). Note that the standard errors are calculated by the delta method.

The PPP water operation also seems to benefit from economies of custom density (*ECD*) defined in Equation (5). The estimated *ECD* is significantly greater than unity, meaning that a 1-percent increase in both water and sewerage connections would raise the total cost by less than 1 percent, while holding other conditions constant; thus, an increase in network size is profitable for operators.

Table 3. Estimated Cost Elasticity

Product	Elasticity	Std. Err.
Yw	0.769	0.022 ***
Ys	0.101	0.005 ***

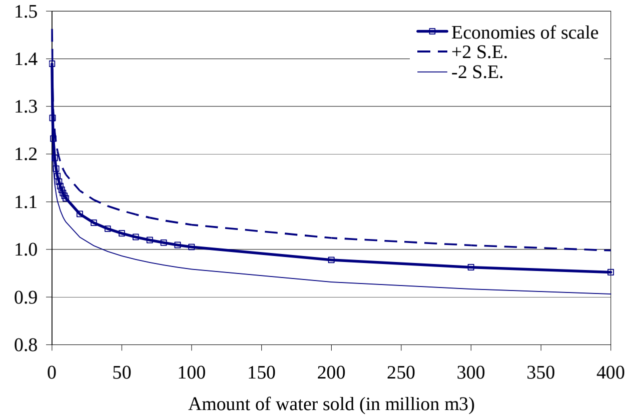
Table 4. Estimated Economies of Scale and Customer Density

	SE or *ECD*	*Std. Err.*
Economies of scale	1.149	0.026 ***
Economies of customer density	1.214	0.013 ***

Importantly, the empirical degree of economies of scale and customer density may differ depending on reference points. As shown in Figure 4, economies of scale tend to diminish quickly as production increases. When the amount of water sold exceeds about 40 million cubic meters (m^3), the expected scale effect becomes insignificant in a statistical sense. It is noteworthy that the PPP water operators may continue to benefit from economies of scale even beyond this threshold. But the impact is statistically ambiguous. When the level of water supply exceeds 400 million m^3, the operation will suffer from diseconomies of scale; *SE* becomes significantly lower than one. Note that the figure depicts the impact of water production (Y_w) on the degree of scale economies while keeping other variables constant at their means.

The result is consistent with the pioneer industrial literature in this industry. Clark and Stevie (1981) find that the most efficient water utility size is about 221 million m^3 (or 58,300 million gallons) of water supply per year. In terms of service area, the optimal size is approximately a 9½-km (or 6-mile) radius circle in their study; the estimated marginal cost can be minimized when the service distance from the central operation point becomes 9½ km.

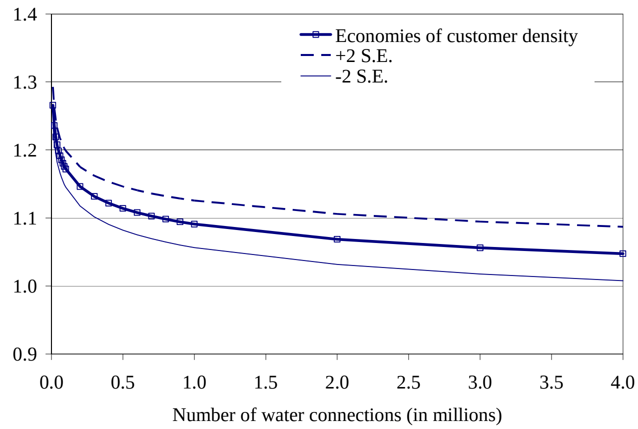
Figure 4. Estimated Economies of Scale Depending on Water Production



The speed at which economies of customer density diminish is relatively slow compared with the case of economies of scale. Figure 5 shows the estimated economies of customer density (*ECD*) depending on the number of water connections (Z_w). Even if the water distribution network is quite sizable, *ECD* tends to be significantly greater than one.

As shown in Figure 3, the majority of PPP water transactions involve the network with less than 400,000 connections. The maximum size in our sample is about 600,000 (Table 1). Around those levels, significant economies of customer density can always be expected. Provided that the network size exceeds four million connections, the customer density effect might diminish.

Figure 5. Estimated Economies of Customer Density Depending on Number of Connections



IV. DISCUSSION

The estimated degree of economies of scale has a direct implication for designing water-sector PPP transactions. Solely from the point of view of economies scale, there is no rationale for auctioning the water operation with annual water delivery of more than 400 million m^3, presumably in the case of metropolitan and large urban areas. When the size exceeds this level, auctioneers should consider the possibility to unbundle the transaction to several zonal contracts. Although there is no such case in our sample, the whole PPIS Database includes 103 utilities with annual water sales of 400 million m^3 or above.

Recall that large contracts cannot fully exploit the competition effect because they usually require prospective firms to have had similar experiences in the past. There are a few operators that are involved in large-scale PPP transactions in the water sector. The unbundling strategy is conducive to enhancing competition and improving auction efficiency.

Conversely, auctioneers may have to adopt the bundling strategy, if each contract involves water supply of less than 40 million m^3. Such small transactions would suffer from unrealized economies of scale. One policy guideline is to put into a single contract several small-scale operations in small cities or rural areas. However, it is worth noting that this bundling criterion is more ambiguous to interpret than the unbundling strategy in the sense that the outputs in the estimated cost function are implicitly assumed to be produced within a single system. Thus, the estimation result is applicable for the case where multiple water systems adjoin and could be connected with each other. But it may not suitable to the situation where several separate water systems are intended to be bundled. Although bundling can still bring about certain economies of scale by pooling financial and managerial resources and skilled labor force, geographical proximity may be necessary.

Kim and Lee (1998), estimating the cost structure of (public) local water supply services in Seoul, suggest that the total production cost could be reduced by about 10 percent if 42 local areas in the city were merged into four submarkets. The grand integration into a single operator could decrease the cost by 47 percent. Too small-scale operation is not desirable.

Interestingly, the 1993 Mexico City's experience appears broadly consistent with our estimation result. At time of introducing the management contract, the water production amounted to 1,113 million m^3, and the uncounted for water was estimated at 51 percent (Haggarty *et al*., 2002; Shirley and Ménard, 2002). Hence, the amount of water sold exceeds our threshold, i.e., 400 million m^3. Since the city was divided into four zones, the average water sold was approximately 140 million m^3, which is above the lower threshold to exploit economies of scale to the maximum extent.

In the Buenos Aires water concession case, the amount of annual water production reached 1,402 million m^3 with an uncounted-for-water rate of 45 percent in 1993. The authorities could have to divide the operational area to at least three zones in order to encourage competition further. The transactions with 700 million m^3 of annual water sales are absolutely exceptional (as shown in Figure 3). However, there are a certain number of water companies who have operated with the production scale on the order of 100–300 million m^3.

The Conakry water lease contract may have been too small to take advantage of economies of scale at the time of the transaction, because its annual water production amounted to 16 million m^3 but the rate of unaccounted for water was about 60 percent (Ménard and Clarke, 2002). The rate improved to less than 50 percent by the mid-1990s. The level of water distribution loss is apparently an important parameter to be considered for having a right size of contract.

Notably, bundling or unbundling is merely one of the measures to increase competition; there are many other possible design flaws that could produce inefficient auction outcomes. For instance, if a transaction is separated into multiple contracts, the demand reduction equilibrium might take place, which has an anti-competitive effect (Ausbel and Cramton, 2002).[7] Renegotiation after the award, which stems from the bidders' strategic low-balling strategy on the auction stage, is also frequently criticized in the PPP market (e.g., Guasch, 2004). Prequalification may be an important policy device to prohibit bidders who have insufficient and doubtful capability from submitting unrealistically low-priced bids (Cripps and Ireland, 1994; Branco, 1997; Ware *et al*., 2007).[8] Whether to allow (large) bidders forming a bidding coalition remains open to argument (e.g., Cho et al., 2002; Iimi, 2004).[9] Explicit collusion and corruption are out of the question.

Finally, the above result does not necessarily contradict the existence of small-scale water supply and sanitation service providers, such as community water vendors. Particularly in remote areas, many people in developing countries have no access to utility services and depend on small private or communal service providers (e.g., WSP, 2007). However, small-

[7] Ausbel and Cramton (2002) demonstrate that in auctions where bidders desire to purchase multiple items at a market-clearing price, large bidders have an incentive to reduce demand in order to pay less for their winnings.

[8] Theoretically, a two-stage selection based on both quality and price bids may be supported (Branco, 1997). As per Ware *et al*. (2007), however, the qualification process may tend to be corruption- and collusion-prone in practice.

[9] In theory, there is an incentive for bidders to divide themselves into two bidding consortia under the free interaction circumstances (Cho *et al*., 2002). Empirically, some joint bidding has been found pro-competitive.

scale services are usually much more expensive than utility tariffs, most likely because of a lack of economies of scale in operation.[10]

V. Conclusion

In water-sector PPP transactions, one of the alleged concerns is that there is little market competition at the auction stage. The worldwide database indicates that the degree of competition is lowest in the water sector among infrastructure industries. In the majority of water transactions, there has been no competition. The average number of firms that participate in the competitive bidding process is merely 2.2 in Latin America.

The paper examined a tradeoff between the competition effect at the auction level and potential economies of scale in service operation. If the authorities design a large-scale PPP water transaction, it is expected to exploit operational scale economies. But the competition effect may have to be sacrificed.

The paper found that the density distribution of the operational size of the past PPP transactions is very skew in the water and sewerage sector; hence, a small number of firms are allowed to participate in the auction, if the contract involves sizable operation. The selection of the contract size could be a very restrictive condition that excludes many prospective bidders.

Using a large PPP transaction database, the cost function of the water-sector operation is estimated. The estimated overall scale effect is found significant and positive. But economies of scale tend to diminish quickly as production increases. When the amount of water sold exceeds about 40 million m^3, the statistical significance of economies of scale would

[10] WSP (2007) shows that private small-scale water and sanitation services in Peru are 15 times as expensive as utility services. At the same time, however, 6.7 million or 24 percent of total population of Peru do not have access to water supply services and are dependent on some small-scale service provision.

disappear. Moreover, if the level of water supply exceeds 400 million m^3, the operation will suffer from diseconomies of scale.

A tentative quantitative policy implication is that there is no rationale for auctioning the water operation with annual water delivery of more than 400 million m^3. To enhance the competition effect, auctioneers should consider the possibility to unbundle the transaction to several contracts.

On the other hand, auctioneers may desire to put several small-scale operations into a single contract, if each operation involves water supply of less than 40 million m^3. Such small transactions could not take full advantage of economies of scale in operation. Notably, these thresholds are a tentative conclusion only from the point of view of economies scale, ignoring many other relevant factors.

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