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# Optimizing the Size of Public Road Contracts

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## Abstract

Procurement packaging has important effects on not only the bidders' bidding behavior, but also contractors' performance. By changing the size of public contracts, procurers can encourage (or discourage) market competition and improve contract performance, avoiding unnecessary cost overruns and project delays. In practice, there is no single solution about how to package public contracts. With procurement data from road projects in Nepal, this paper examines the optimal size of road contracts in rural areas. The optimum varies depending on policy objectives. To maximize the bidder participation, the length of road should be about 11 kilometers. To minimize cost overruns and delays, the contracts should be much larger at 17 and 21 kilometers, respectively. Compared with the current procurement practices, the findings suggest that procurers take more advantage of enlarging road packages, although contracts that are too large may increase the risk of discouraging firms from participating in public tenders.


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# OPTIMIZING THE SIZE OF PUBLIC ROAD CONTRACTS [‡]

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Key words: Public procurement; rural roads, auction theory; competition; market entry.

JEL classification: D44, H54, H57, D82.

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## I. INTRODUCTION

Public procurement is an important policy instrument to use limited public resources effectively. Procurement packaging has a particularly important effect on not only the bidders' bidding behavior but also their entry strategy. In general, larger contracts can reduce the unit costs of infrastructure procurement because of expected economies of scale in procurement vis-à-vis production. At the same time, however, if a public contract is too large, there may be only a few firms that could undertake it, especially in developing countries. Potential contractors normally decide whether to apply for public tenders, depending on size of contracts (e.g., Ware *et al*., 2007; Estache and Iimi, 2011).

The contract performance of public works may also be affected by the way contracts are packaged. One of the problems of designing large contracts in complex projects, such as infrastructure works, is the poor performance of contractors in implementing the works. In general, large contracts tend to involve more project risks and are therefore likely to incur cost overruns and project delays. Nine out of ten transport projects experienced cost overruns (Flyvbjerg *et al*., 2002). In Africa, road project delays are 10 months on average (Alexeeva *et al*., 2008). Each year of delay would add on average $4.6 million to a project cost of $100 million in the transport sector (Flyvbjerg *et al*., 2004).

In practice, there is no single solution to packaging public contracts. Procurement planning is often fairly flexible. For instance, the World Bank's guidelines, which are consistent to many other foreign donors' guidelines, stipulate that "[t]he size and scope of individual contracts will depend on the magnitude, nature, and location of the project. For projects requiring a variety of goods and works, separate contracts generally are awarded for the supply and/or installation of different items of equipment and plant" (Guidelines: Procurement under IBRD Loans and IDA Credits, clause 2.3, World Bank). At the same time, "[i]n certain cases the Bank may accept or require a turnkey contract under which the design and engineering, the supply and installation of equipment, and the construction of a complete facility or works are provided under one contract" (clause 2.5). Therefore, how to design a procurement plan is left to procurers or executing agencies.

In theory, whether to bundle or unbundle relevant contracts being auctioned is one of the most important policy choices for auctioneers. The multi-unit auction literature tends to favor unbundled procurements as long as competition is secured. If there are only two bidders for an arbitrary number of contracts, the auctioneer should bundle all the contracts 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 contracts, which of necessity become relatively smaller (Palfrey, 1983). The choice of (un)bundling is also related to the cost of entry for bidders, which is interpreted as the extent to which two components are technically different. If the cost of entry is sufficiently large, separate auctions are more likely to be preferable (Chakraborty, 2006).

The current paper discusses pros and cons of enlarging contract packages in public procurement. With detailed procurement data from rural road projects in Nepal, it aims at examining the optimal size of road contracts from different perspectives. It estimates the firms' bidding strategy with the endogeneity of bidder participation taken into account. Unlike the existing empirical auction literature, this paper also casts light on the ex post contract performance, which could be affected by the size of contracts. The remaining sections are organized as follows: Section II summarizes pros and cons of enlarging the size of public contracts from a general point of view. Section III describes our data and Section IV develops the estimation methods. Section V discusses the main estimation results and policy implications. Then Section VI concludes.

## II. PROS AND CONS OF ENLARGING PUBLIC CONTRACT PACKAGES

There are pros and cons of enlarging public contracts in general (Table 1).[1] First of all, public procurement normally exhibits economies of scale. Small-scale procurement tends to fail to internalize possible economies of scale and other spillovers across territories and/or sectors. In small jurisdictions or in small island countries, for instance, public procurement costs tend to be high (Table 2). In Africa the median costs of road construction and rehabilitation involving less than 50 kilometers of road are also found significantly higher than for larger projects (Figure 1).

**Table 1. Advantages and disadvantages of large and small procurement packages**

| | Large contracts | Small contracts |
|---|---|---|
| Bidder participation | High expected profitability<br>High entry barrier if prequalification conditions are imposed | High transaction cost of preparing proposals<br>Low accountability of procurers and high vulnerability to corruption |
| Procurement costs | Economies of scale in procurement | Aggressive bids by entrants (asymmetric auction theory)<br>Instability of collusive arrangements because of unexpected entry |
| Administrative costs | Low cost of evaluating a few experienced bidders and their bids<br>High evaluation cost per bid because of more technical complexity involved | High cost of evaluating a number of inexperienced bidders and their bids |
| Ex post adjustments (e.g., cost overruns and delays) | More flexibility for contractors to accommodate shocks<br>Large project risks (construction and financing)<br>Large incentives for contractors to renegotiate their contracts<br>Little bargaining power for procurers in renegotiating contracts | Little flexibility for contractors to accommodate shocks |

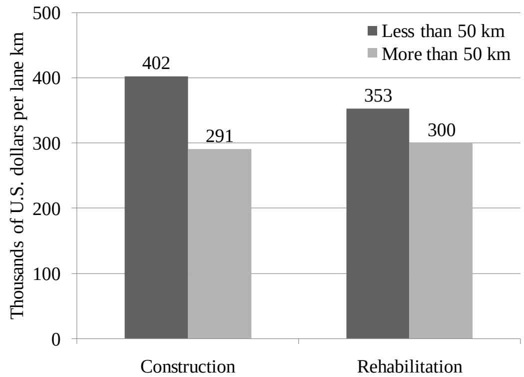
[1] See more discussion in Estache and Iimi (2011).

**Table 2. Infrastructure procurement costs in East Caribbean states**

| | Labor | Materials | Equipment |
|---|---|---|---|
| Argentina | 1 | 1 | 1 |
| East Caribbean [1] | 1.79 | 2.55 | 3.75 |

Source: World Bank, 2008a.
Note: 1/ Dominica, St. Vincent, Grenada, and St. Lucia.

**Figure 1. Unit costs of road construction maintenance in Sub-Saharan Africa**




Source: Africon, 2008.

From the competition point of view, small contracts can lower the entry barrier. This has three effects. First, the competition among bidders will increase if the size of contracts is reduced. Small and medium-sized enterprises (SMEs) often constitute the vast majority of enterprises in the economy. But their capacity to undertake public contracts may be technically and financially limited. Therefore, downscaling the contract size could encourage SMEs to enter the market. Second, fringe entrants are particularly important to break hidden collusive arrangements among incumbent bidders. Without new entry, the market tends to be collusive among incumbent players (e.g., Porter and Zona, 1993). Finally, fringe bidders often submit aggressive bids (Maskin and Riley, 2003). Empirically, entrants are in fact found to be more aggressive, especially at the lower end of the bid distribution, in the Oklahoma State's road auction market (De Silva and others, 2002; De Silva, Dunne, and Kosmopoulou, 2003).

However, the endogenous auction theory also suggests that too small public contracts can be an entry barrier, because preparing financial and technical proposals is a time-consuming task for potential contractors. Regardless of the size of contracts, this is a sunk cost for them. Therefore, the bidder participation can be reduced if the entry cost is relatively high compared to the expected probability of winning the contract (e.g., McAfee and McMillan, 1987; Levin and Smith, 1994). This may be of particular relevance to the following analysis focusing on small public road works in rural areas.

From the administrative point of view, it would be costly for procurers to divide a road project into a number of small contracts. If a large number of firms apply for each small contract, it would take more time for procurers to evaluate all the bids and make a contract. There is also an institutional risk in small-scale infrastructure procurement. Small transactions are often prepared using weaker, less formal, and less transparent contracts than those used for large contracts. As a result, the stakeholders involved have difficulty disputing formally. This leads to corruption and collusion among both public officials and private contractors (e.g., Besant-Jones, 2006; Estache and Iimi, 2011). In Africa the costs of rural boreholes are sometimes four times that in some parts of Asia (WSP-Africa, 2005; Plummer and Cross, 2007).

Finally, the size of contracts may possibly affect the performance of contractors carrying out the works. For technical reasons, large contracts involve more project risks of construction and financing. At the same time, there are also institutional issues that can explain ex post contract incompliance. In large and complex projects, such as infrastructure works, rebidding is usually extremely costly once the works are started. Procurers have little bargaining power at the stage of post-award renegotiation. Knowing this, firms have strong incentives to take the low-balling strategy to undercut their normal bids, and to initiate renegotiation later on. In theory, Bajari and Tadelis (2001) highlight a clear tradeoff between providing right incentives and reducing ex post renegotiation costs. Fixed-price contracting can strongly incentivize contractors to contain costs but will require more time and costs for designing a more detailed contract and avoid inefficient ex post renegotiation. In addition, if the contract turns out incomplete despite all these ex ante efforts, the cost of adjusting the contract would likely be significant. By contrast, under more flexible arrangements, such as cost-plus contracts, ex post adjustments are less costly, but there is no incentive for cost reduction.

## III. DATA

Our empirical data are collected from over 150 rural road contracts in 19 districts of Nepal where the World Bank has been assisting the Rural Access Improvement and Decentralization Project (RAIDP).[2] They are located mostly in the Tarai area (Figure 2). In each district, on average 8 road contracts were reviewed—half from World Bank-financed projects and half from government-owned projects. In Nepal the rural road projects are basically implemented at the local level. With the assistance of the Department of Local Infrastructure and Agricultural Roads (DOLIDAR), the District Development Committees (DDCs) are designing, procuring and managing rural road civil works and services.

Nepal is one of the least developed countries. According to the 2011 census, about 26.6 million people live in the country. About 34 percent still live on less than $1.25 a day at 2008 international prices. Gross domestic product (GDP) per capita was only $430 in 2009. The country has some 17,000 km of road network, which is among the lowest road densities in the world. The vast majority of rural residents have to spend more than 30 minutes to access paved roads. About one-third do not have any paved road within more than 3 hours in Nepal.

The sample contracts are relatively small. In Nepal the rural road standards are not particularly high. The average unit cost of rural road upgrading works is about NRs1.6 million or $23,000 per km.[3] The "size of contracts" also seems fairly small at 7km on average but ranges from less than 1 km to more than 30 km (Figure 3). Depending on size, the administrative efficiency of procurers or DDCs contracting out works may differ. In some cases, it takes more than 6 months (Figure 4). The contract performance also varies across contracts. Most of the contracts did not incur any cost overruns, but some did (Figure 5). The average cost overrun rate is about 4 percent with some cost overruns offset by cost underruns.

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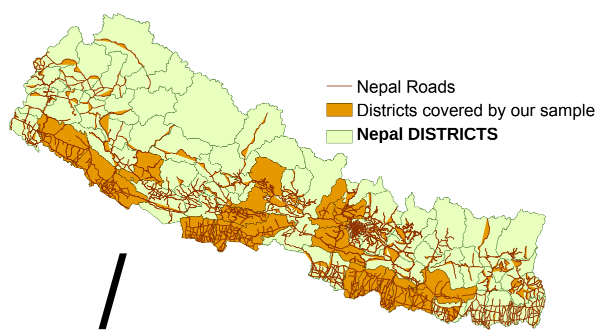
[2] One of the 20 districts assisted by the RAIDP has not yet had road work contracts that can be evaluated at the time of our data collection.

[3] The road upgrading unit cost is estimated at $360,000 in Africa (Alexeeva *et al*., 2008). Foster and Briceno-Garmendia (2010) also estimates the road rehabilitation cost at $200,000 to $500,000 per km, depending on country and the scale of roads.

By contrast, many contracts seem to have experienced significant project delays (Figure 6). The sample road works delayed on average 50 percent compared to the original work schedule.

The summary statistics are shown in Table 3. The average number of bidders is six. In the project areas, more than 10 security incidents happened during the 3 months before the contracts, but the significance seems to depend on location. The number of potential contractors may be about 22 firms, out of which only 6 firms actually applied for the competition. On average 26 days are given for firms to prepare their bids. But in some cases, the preparation period looks unreasonably tight, even though rural road works are considered to be simple. In these cases, the entry barrier may be perceived to be significantly high, because there are few firms that could assess work specifications and prepare bids within 6 days.

**Figure 2. Existing road network and districts covered by our sample**




Source: Benamghar and Iimi (2011).

**Figure 3. Probability distribution of road length in the sample**

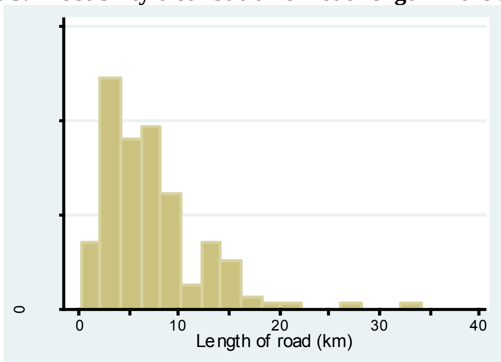



**Figure 4. Probability distribution of number of days required to evaluate bids and sign a contract**

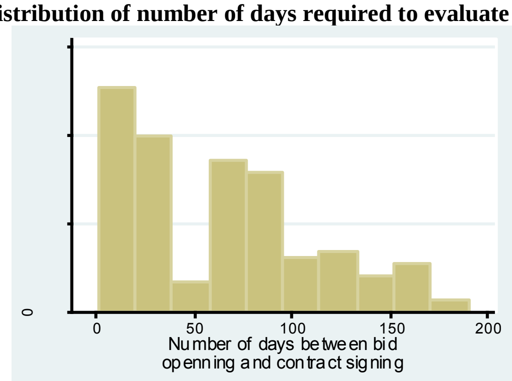



**Figure 5. Probability distribution of cost overruns**

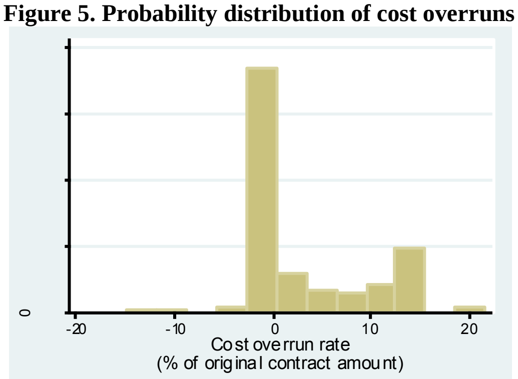



**Figure 6. Probability distribution of project delays**

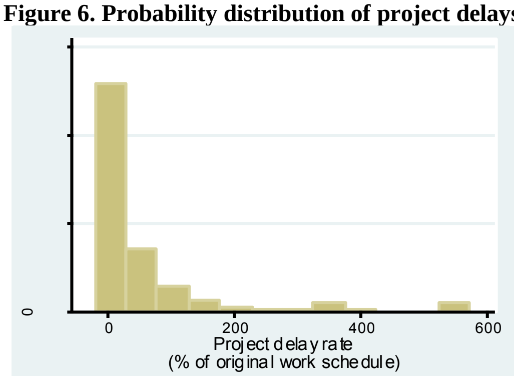


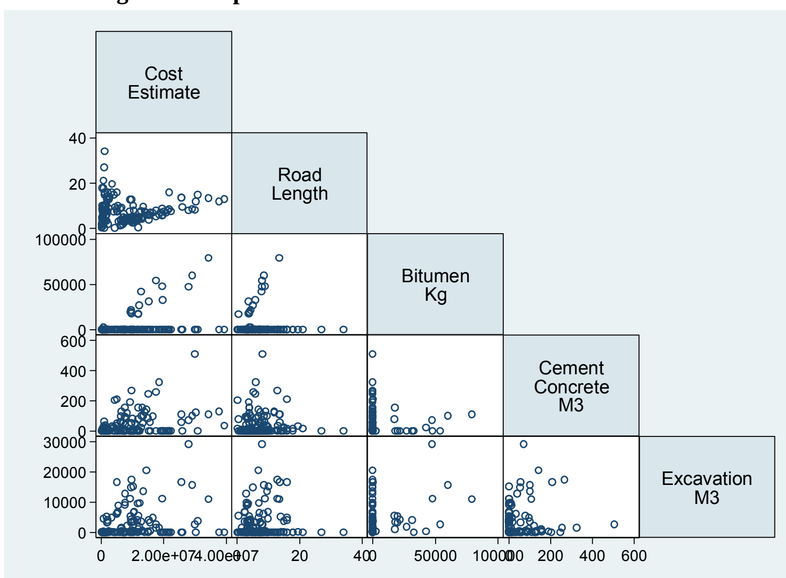
**Table 3. Summary statistics**

| Variable | Abbreviation | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|---|
| Predicted principal component score | *pca* | 154 | 0.00 | 1.69 | -1.86 | 7.78 |
| Length of roads (km) | *length* | 154 | 7.4 | 5.1 | 0.2 | 34.0 |
| Winning bid amount (NRs million) | *bid* | 113 | 7.4 | 8.1 | 0.3 | 37.6 |
| Number of bidders | *num* | 154 | 6.0 | 3.9 | 1.0 | 16.0 |
| Cost overrun rate (percent) | *costover* | 139 | 4.0 | 6.4 | -14.8 | 21.7 |
| Project delay rate (percent) | *delay* | 138 | 58.6 | 119.8 | -19.3 | 571.4 |
| Number of days required to award a contract | *govteff* | 154 | 64.2 | 47.6 | 1.0 | 190.0 |
| Number of security incidents during the three months prior to each tender | *securitybefore* | 113 | 10.8 | 10.0 | 0 | 38 |
| Line distance between project and firm origin districts | *dist* | 113 | 93.8 | 143.9 | 0 | 477.47 |
| Dummy for the same dominant ethnicity between project and firm origin districts | D(*ethnicity*) | 113 | 0.6 | 0.5 | 0 | 1 |
| Dummy variable for postqualification of bids | D(*postqualify*) | 154 | 0.9 | 0.3 | 0 | 1 |
| Number of bidders purchasing bidding documents | *bdnum* | 119 | 22.4 | 17.8 | 4.0 | 107.0 |
| Bid preparation period (days) | *bidtime* | 119 | 26.0 | 9.2 | 6.0 | 52.0 |
| Number of security incidents during the project implementation | *securityduring* | 139 | 35.8 | 48.7 | 0 | 280.0 |
| Precipitation during the project implementation (mm) | *rainduring* | 139 | 1743.4 | 1793.1 | 0 | 8774.2 |
| Difference between the winning bid and the second lowest bid (NRs million) | *lowball* | 139 | 2.7 | -29.6 | 6.29043 | 0.0 |
| Memorandum items: | | | | | | |
| Engineering cost estimate (NRs million) | *cost* | 154 | 8.6 | 0.2 | 39.4 | 0.0 |
| Number of lanes | *lane* | 154 | 1.0 | 0.2 | 1.0 | 2.0 |
| Thickness of road surface (mm) | *thickness* | 154 | 6.6 | 14.5 | 0.0 | 150.0 |
| Gravel (m3) | *gravel* | 154 | 2034.9 | 2505.4 | 0.0 | 18600.0 |
| Bitumen (kg) | *bitumen* | 154 | 3407.5 | 11977.7 | 0.0 | 79029.6 |
| Earthworks (m3) | *earth* | 154 | 7607.2 | 11659.7 | 0.0 | 93403.0 |
| Brickworks (m3) | *brick* | 154 | 62.8 | 161.3 | 0.0 | 1204.1 |
| Gabion (m3) | *gabion* | 154 | 239.0 | 743.9 | 0.0 | 8400.0 |
| Excavation (m3) | *excavation* | 154 | 2464.4 | 4851.7 | 0.0 | 29266.6 |
| Cement concrete (m3) | *cement* | 154 | 36.9 | 72.4 | 0.0 | 507.8 |

## IV. Methodology

The basic analytical framework follows Benamghar and Iimi (2011), but this paper focuses more on examining the impacts of changing the size of contracts. One of the empirical issues that need to be addressed is how to measure the size of contracts. Unlike simple government purchases, such as office supplies, infrastructure contracts are by nature multidimensional. In the road sector, "large contracts" tend to involve longer segments of roads, which also normally require more inputs, such as bitumen and cement. As a result, the engineering cost estimates of those large contracts also tend to be large (Figure 7). In theory, it is not easy to measure the size of these road contracts by any single measurement.

**Figure 7. Simple correlations between size-related variables**



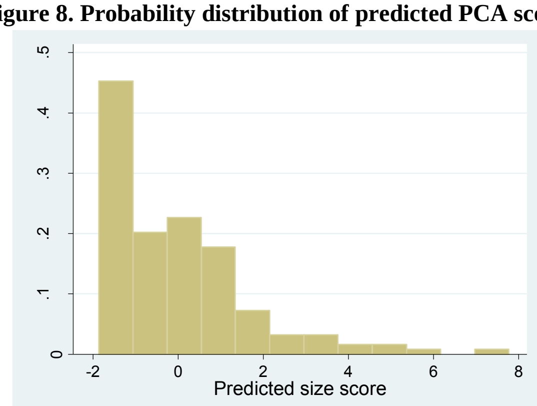

Note: Only selected variables are shown in the figure.
Source: Author's calculation

For empirical purposes, two approaches are adopted to define the size of contracts. First, the dimensionality is reduced by using the principal component analysis (PCA) technique. The PCA generates the following first component with the largest variance among all unit-length linear combinations of our 11 size-related variables:

$$pca = 0.53cost + 0.04length - 0.05lane + 0.05thickness + 0.42gravel + 0.17bitumen$$
$$+ 0.43earth + 0.32brick + 0.18gabion + 0.16excavation + 0.38cement \qquad (1)$$

Note that the variables included are standardized to have a mean of zero and a standard deviation of one. This component explains about one-fourth of the total variance. As expected, the engineering cost estimate is found to be the most important element to explain the variation among these size-related variables. Using this component, a new variable, *pca*, is calculated (Figure 8). Not surprisingly, the figure resembles the probability distribution of the road length (Figure 3). One disadvantage, however, is that the principal component estimator may be difficult to interpret, because the estimator is a mixture of all the original coefficients (e.g., Greene, 1997). Particularly from the practical point of view, the estimation results will be difficult to use to discuss how to package the procurement contracts in practice.

**Figure 8. Probability distribution of predicted PCA score**




Source: Author's calculation.

Another approach to measure the size of contracts is to choose one single variable. This is more practical and straightforward. The length of roads is considered as a good proxy to this end, because the engineering cost estimate is basically calculated based on the road length and unit costs. In addition, how many input materials (such as cement and bitumen) are needed is also dependent on the length of roads. Therefore, the following analysis focuses on the length of roads, i.e., *length*.

To investigate the bidding strategy of firms, the following symmetric equilibrium bid function is considered (e.g., Porter and Zona, 1993; Gupta, 2002; Estache and Iimi, 2009; 2010; 2011):

$$\ln bid = \alpha_0 + \alpha_1 size + \alpha_2 size^2 + \alpha_3 \ln num + X'\alpha_4 + \varepsilon_1 \qquad (2)$$

where *bid* is the winning bid normalized by its engineering cost estimate. *size* is one of the two size variables: *pca* and *length*. *num* is the number of bidders who participated in an auction. *X* controls for other contract- and bidder-specific heterogeneity, such as security instability at the work location and the distance between a project site and a contractor's location. A set of dummy variables representing project location and bidders' origin districts are included in *X*, because local firms may have the different cost advantage than outside companies.

One empirical issue in estimating Equation (2) is that the bidders' entry strategy is likely to be endogenous. To deal with this endogeneity, two instrumental variables are considered:

$$num = f(bdnum, bidtime, size, size^2, X; \beta) \quad (3)$$

where *bdnum* is the number of firms who bought the bidding documents. This is a proxy for the maximum pool of contenders that could participate in each auction and analogous to the number of plan holders or eligible bidders in the existing literature (e.g., Haile, 2001; Paarsch, 1997; De Silva, Dunne, Kankanamge and Kosmopoulou, 2008). Another instrument is *bidtime*, which is the number of days granted for firms to prepare bids. The bid preparation is a costly and time-consuming task for contractors. The shorter bid preparation period would impose an extra burden on contractors, particularly less experienced firms. The equation can be estimated by a generalized count regression model (e.g., Li and Perrigne, 2003; Li and Zheng, 2006; Ohashi, 2009).

Public infrastructure contracts are often incomplete and unenforceable. Many projects have incurred cost overruns and delays (e.g., Flyvbjerg *et al*., 2002; Alexeeva *et al.*, 2008). To examine the effects of the contract size on these ex post contract adjustments, the following equations are considered:

$$costover = \gamma_0 + \gamma_1 size + \gamma_2 size^2 + X'\gamma_3 + \varepsilon_3 \quad (4)$$

$$delay = \delta_0 + \delta_1 size + \delta_2 size^2 + X'\delta_3 + \varepsilon_4 \quad (5)$$

*costover* is the rate of cost overruns relative to the original contract amount and *delay* is the rate of project delays relative to the original project duration.

Finally, to examine the possible effect of enlarging the size on the procurer side, the following equation is examined:

$$\ln govteff = \phi_0 + \phi_1 size + \phi_2 size^2 + \phi_3 \ln num + X'\phi_4 + \varepsilon_5 \quad (6)$$

where *govteff* is the number of days required to award a contract after the bid opening. This aims at representing the government (in)efficiency in evaluating bids, negotiating the lowest bidder, preparing the details of the contract and signing the contract. This tends to be a lengthy process in particular in developing countries.

## V. Main estimation results and policy implications

Equations (2) to (6) are estimated separately by the ordinary least squares, instrumental variable (IV) and zero-truncated negative binomial models.[4] With the predicted PCA scores used to measure the size of road contracts, one optimal point is found: The number of bidders could be maximized when the size index is about 3.5 (Figure 9). As discussed, it is ambiguous how to interpret this score in a practical manner. However, the concavity is evident. Recall that the constructed size index is a linear combination of the standardized size-related variables. In addition, it is clear that this optimum does not seem to be achieved under the current procurement practices. Given the distribution of the predicted principal component scores (see Figure 8), there are only 7 observations (out of 155) that have

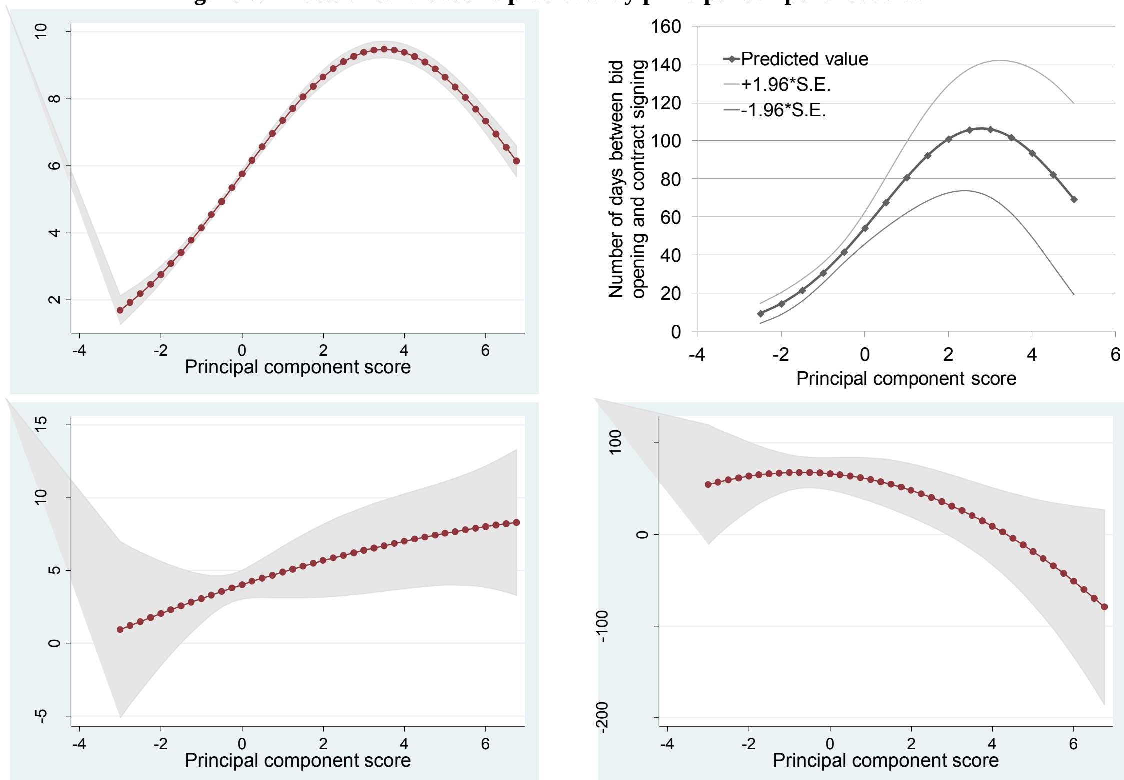
[4] See Appendix for the detailed estimated equations.

principal component scores of more than 3.5. Hence, to promote the bidder participation, the contract size needs to be augmented.

Another finding in Figure 9 is that the procurer's efficiency would initially decline as the size of contracts increases. This may reflect the negative effect of enlarging the contract size. Large contracts would take more time to evaluate. In addition, as discussed above, more firms would apply for large contracts. As the result, procurers have to spend more time to evaluate a number of bids and bidders for larger contracts. But the predicted number of days required for bid evaluation could decline, when the contract size exceeds a certain level. This may be because firms that can apply for very large contracts (in our sample) are likely to have more experiences and reputation. Therefore, the evaluation process can be less inefficient than the case that a number of inexperienced contractors would be evaluated.

The impacts of the size of contracts on ex post contract adjustments remain unclear, because of large standard errors. The coefficients of $pca$ and $pca^2$ are found statistically insignificant (see Appendix).

**Figure 9. Effects of contract size predicted by principal component scores**




With the contract size measured by a single variable, *length*, more optimal points were found. The bidder participation could be maximized when the length of road is about 11km (Figure 10).[5] This is about 80 percentile of the road length in our sample. Beyond this level, the bidder participation would become limited, possibly because of local contractors' capacity constraints. Below this optimum, the bidder participation would also be limited, because the firms' transaction costs of preparing the bid strategy and entering the market seem to be prohibitively high. Too small contracts are not profitable enough to enter the competition. This concavity is consistent to the above result with PCA scores.

From the procurer point of view, packaging large contracts would help to improve their administrative efficiency in the contracting process. The number of days required to evaluate

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[5] The finding seems consistent to the perception of the public procurement practitioners in Nepal that more contractors would apply if the contract size ranges from 10km to 15km.

bids is estimated to decline, as the contract size increases, except for the cases when the contract size is less than 2km. Too small contracts are found to be costly to evaluate, possibly because relatively inexperienced contractors would apply for small contracts. The estimation result indicates that if a work of upgrading a road of 10km or less is contracted out, it would take more than a month to evaluate bids and make a contract.

Regarding the contract performance, relatively large contracts in our sample are estimated to have less, not more, cost overruns and project delays. Although the statistical errors remain large, this evidence is more significant than the previous results. Cost overruns could be minimized by increasing the size of contract packages up to 17km. The optimal size to restrain project delays is even larger at 21km.

It is considered that several reasons exist behind these findings. First, large contracts are more likely to be contracted out to skilled and reputable firms. Financial, technical and managerial capacities are usually required for public infrastructure projects. Thus, only experienced firms could apply for large contacts. They are presumably better at delivering contracted works at agreed costs on schedule.[6] Second, large transactions may allow contractors more flexibility in scheduling and costing their works. Recall that our sample contracts are all small by normal standards of public infrastructure procurement.[7] Provided that some unexpected events, such as heavy rain and strikes, happen, contractors could accommodate those shocks if the contract schedule is long enough and the value of the transaction is sufficiently large. Some work components may overrun the intended costs, but other components may underrun the original estimates. By contrast, there will be little flexibility left for contractors to adjust their work plans if the contracts are small.

[6] There is a practical view that it is important to ensure the quality of public work, while recognizing competition would result in lower procurement costs. Unrealistically low bids have been observed in practice. Bid prices are often found to be 20-50 percent below the cost estimates. It may be important to ensure the eligibility of contractors based on their past performance.

[7] Considering the market absorption capacity carefully, the Nepal government has gradually been increasing the size of public road contracts in recent years.

The benefit from greater flexibility in large contracts is found to be dominated by the project risk that inherently increases as the size of contracts increases. This is more consistent to the conventional view: The larger contracts, the greater risks of project delays and cost overruns (e.g., Estache and Iimi, 2011).[8] Comparing these two risks, the estimation result indicates that project delays are a more challenging issue in this market, because the estimated optimal size minimizing delays is larger than the size minimizing cost overruns. This appears consistent to the view that contractors are normally not allowed to add to the contract amount in rural road projects, which are technically simple. On the other hand, the road works in rural areas are vulnerable to exogenous shocks, such as heavy rains, causing project delays. This is more difficult to avoid. In the current procurement practices, few contracts involve a road of 20km or more (see Figure 3). Consequently, massive project delays have happened.

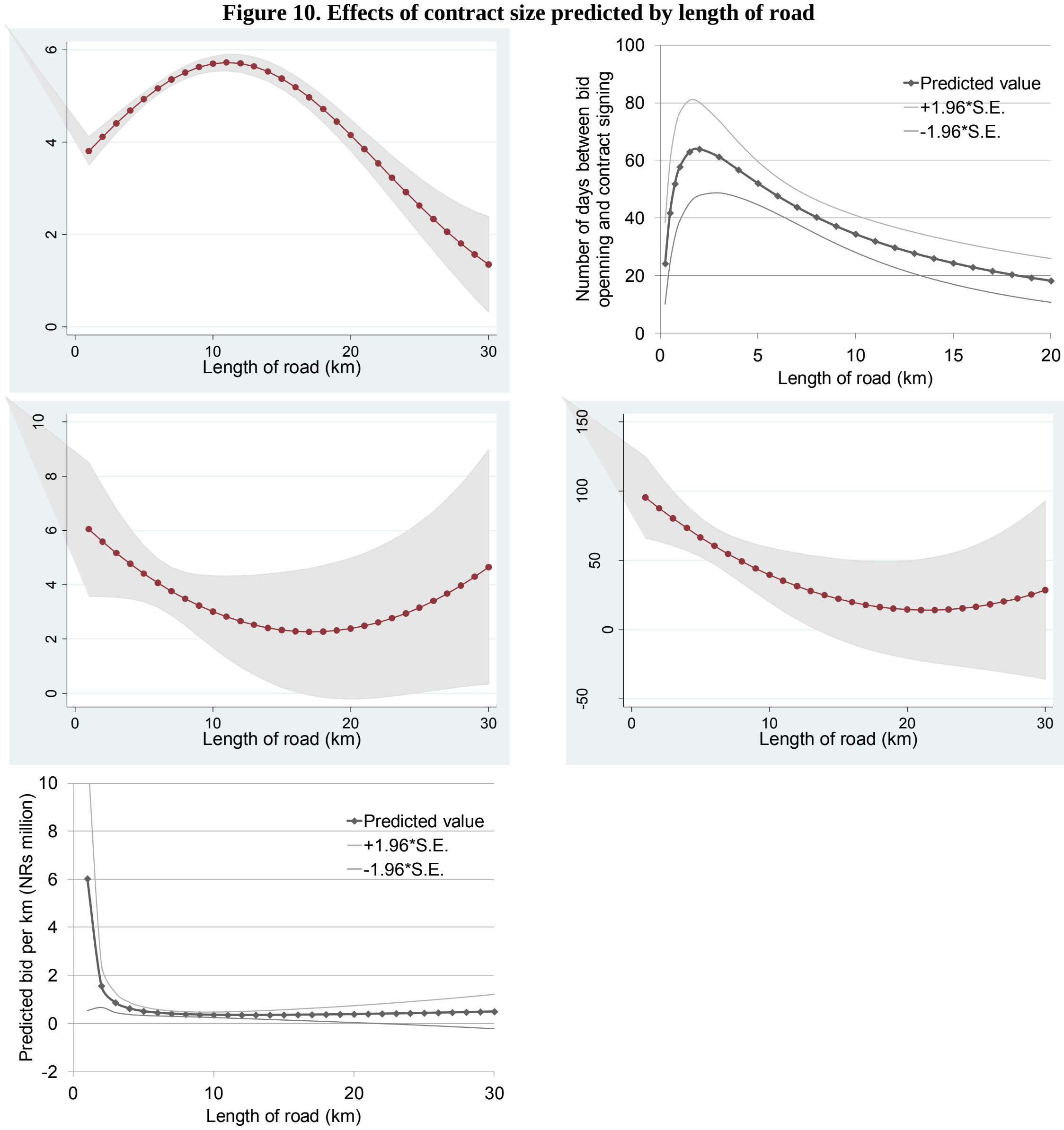
Finally, the unit costs are calculated by the delta method. Unlike the PCA estimation, the single-index approach allows us to predict the unit costs of standardized road works. The average cost function exhibits some economies of scale in procurement. But the predicted unit costs are fairly constant, regardless of the length of roads. The unit cost may be significantly high for a 1- or 2-km road contract. Beyond this level, there are little economies of scale in this market. It is intuitively reasonable because the absolute size of the contracts in our sample is very small. Thus, it may be less likely that the procurement exhibits economies of scale.

In sum, the contract size matters to public road procurement. The optimal size varies depending on policy objectives. The optimum is estimated at 11km if procurers aim to maximize the bidder participation. To avoid cost overruns, the optimal size is about 17km. To reduce project delays, much larger contracts will be needed. The optimal package is a 21km road. These optima do not contradict other policy objectives: Economies of scale in practice would not matter at these levels. The contract efficiency could increase as the

[8] It seems that an additional incentive mechanism is needed for large-scale projects, such as the midcourse review process where the contractual performance would be reviewed from time to time and contractors would be penalized if they do not meet the intermediary targets. This has been used in some of the road projects in Nepal in recent years.

contract size increases. But the marginal efficiency gains in processing procurement may be moderate in numerical terms. Thus, the optimal size of rural road contracts in Nepal could be 11km to 21km.

**Figure 10. Effects of contract size predicted by length of road**



## VI. Conclusion

Procurement packaging has particularly important effects on not only the bidders' bidding behavior, but also their entry strategy. Procurers can encourage or discourage market competition by designing contract packages differently. The performance of contractors is also affected by procurement planning. Some of the poor contract performance, such as cost overruns and delays, may be attributable to flaws of contract design. In practice, there is no single solution about how to package public contracts. Procurement planning is often fairly flexible.

The paper explores the optimal size of public road contracts with the procurement data from rural road projects in Nepal. It found that the procurement and contract performance could be improved by changing the size of public contracts. There are different optima, depending on policy objectives. To maximize the bidder participation, the length of road should be about 11km. To minimize cost overruns and delays, the contracts should be much larger at 17km and 21km, respectively. These point estimates are significantly larger than the current procurement practices. The current average length is only 7km. Therefore, procurers should take more advantage of enlarging road packages in this case, although there is risk that too large contracts could discourage firms from participating in public competitive bidding.

## APPENDIX

**Table 4. Estimation results with principal component scores**

| Dependent variable | *num* | | | ln *bid* | | | ln *govteff* | | | *costover* | | | *delay* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Estimation method | Zero truncated negative binomial | | | IV | | | OLS | | | OLS | | | OLS | | |
| | Coef. | Std. Err. | | Coef. | Std. Err. | | Coef. | Std. Err. | | Coef. | Std. Err. | | Coef. | Std. Err. | |
| *pca* | 0.286 | (0.053) | *** | 0.092 | (0.337) | | 0.484 | (0.080) | *** | 0.909 | (0.743) | | -3.899 | (7.830) | |
| *pca*pca* | -0.041 | (0.011) | *** | 0.064 | (0.073) | | -0.087 | (0.024) | *** | -0.041 | (0.120) | | -2.614 | (1.820) | |
| ln *num* | | | | 2.766 | (1.367) | ** | 0.158 | (0.126) | | -2.279 | (1.011) | ** | -4.476 | (10.787) | |
| *bdnum* | 0.006 | (0.006) | | | | | | | | | | | | | |
| *bidtime* | 0.014 | (0.009) | | | | | | | | | | | | | |
| ln *securitybefore* | -0.008 | (0.009) | | 0.075 | (0.264) | | | | | | | | | | |
| ln *dist* | | | | 1.099 | (0.913) | | | | | | | | | | |
| D(*ethnicity*) | | | | 5.395 | (3.764) | | | | | | | | | | |
| D(*postqualify*) | -0.782 | (0.220) | *** | 0.523 | (0.889) | | 0.659 | (0.324) | ** | 3.006 | (2.486) | | 77.68 | (34.90) | ** |
| ln *securityduring* | | | | | | | | | | 1.248 | (0.788) | | 53.62 | (11.61) | *** |
| ln *rainduring* | | | | | | | | | | -0.396 | (0.394) | | -0.110 | (3.957) | |
| ln *lowbid* | | | | | | | | | | -0.046 | (0.106) | | 3.934 | (1.264) | *** |
| ln *govteff* | | | | | | | | | | 2.009 | (0.660) | *** | 5.192 | (8.925) | |
| Constant | 1.898 | (0.423) | *** | 4.509 | (6.367) | | 2.757 | (0.437) | *** | -5.588 | (6.160) | | -279.9 | (65.6) | *** |
| Obs. | 118 | | | 112 | | | 153 | | | 138 | | | 137 | | |
| Wald chi2 | 523.33 | | | 2304.83 | | | | | | | | | | | |
| R-squared | | | | 0.267 | | | 0.593 | | | 0.490 | | | 0.679 | | |
| *F*-statistics | | | | | | | 13.43 | | | 5.00 | | | 9.13 | | |
| No. of dummy variables: | | | | | | | | | | | | | | | |
| Project districts | 18 | | | 16 | | | 18 | | | 18 | | | 18 | | |
| Bidders' home districts | 0 | | | 18 | | | 0 | | | 0 | | | 0 | | |

Note: Robust standard errors are shown in parentheses. *, **, *** indicate the statistical significance at the 10%, 5% and 1%, respectively.

**Table 5. Estimation results with single measurement, *length***

| Dependent variable | *num* | | ln *bid* | | ln *govteff* | | *costover* | | *delay* | |
|---|---|---|---|---|---|---|---|---|---|---|
| Estimation method | Zero truncated negative binomial | | IV | | OLS | | OLS | | OLS | |
| | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. |
| ln *length* | 0.089 | (0.037) ** | -1.257 | (0.531) ** | 0.307 | (0.109) *** | -0.496 | (0.270) * | -8.360 | (3.413) ** |
| ln *length**ln *length* | -0.004 | (0.001) *** | 0.447 | (0.179) ** | -0.231 | (0.046) *** | 0.014 | (0.008) * | 0.195 | (0.109) * |
| ln *num* | | | 2.881 | (0.921) *** | 0.512 | (0.113) *** | -1.236 | (0.820) | -10.42 | (9.97) |
| *bdnum* | 0.015 | (0.005) *** | | | | | | | | |
| *bidtime* | 0.027 | (0.008) *** | | | | | | | | |
| ln *securitybefore* | -0.008 | (0.010) | -0.035 | (0.266) | | | | | | |
| ln *dist* | | | 0.773 | (0.715) | | | | | | |
| D(*ethnicity*) | | | 3.649 | (2.768) | | | | | | |
| D(*postqualify*) | -0.515 | (0.201) | 2.106 | (0.803) *** | 1.405 | (0.347) *** | 4.417 | (2.635) * | 84.77 | 33.77 ** |
| ln *securityduring* | | | | | | | 1.776 | (0.732) ** | 50.09 | 11.14 *** |
| ln *rainduring* | | | | | | | -0.537 | (0.338) | -0.608 | (4.005) |
| ln *lowbid* | | | | | | | -0.028 | (0.101) | 3.537 | (1.220) *** |
| ln *govteff* | | | | | | | 1.965 | (0.625) *** | -2.090 | (8.074) |
| Constant | 0.636 | (0.400) | 6.711 | (4.280) | 1.562 | (0.462) *** | -6.846 | (4.384) | - 188.18 | 51.37 |
| Obs. | 119 | | 113 | | 154 | | 139 | | 138 | |
| Wald chi2 | 531.45 | | 5483.75 | | | | | | | |
| R-squared | | | 0.248 | | 0.544 | | 0.487 | | 0.669 | |
| *F*-statistics | | | | | 15.51 | | 5.19 | | 9.120 | |
| No. of dummy variables: | | | | | | | | | | |
| Project districts | 18 | | 16 | | 18 | | 18 | | 18 | |
| Bidders' home districts | 0 | | 18 | | 0 | | 0 | | 0 | |

Note: Robust standard errors are shown in parentheses. *, **, *** indicate the statistical significance at the 10%, 5% and 1%, respectively.

## REFERENCE


Africon. 2008. "Unit Costs of Infrastructure Projects in Sub-Saharan Africa." Background Paper No. 11 (Phase I), Africa Infrastructure Country Diagnostic, World Bank, Washington, DC.

Alexeeva, Victoria, Gouthami Padam, and Cesar Queiroz. 2008. Monitoring road works contracts and unit costs for enhanced governance in Sub-Saharan Africa. Transport Papers TP-21, World Bank, Washington, DC.

Bajari, Patrick, and Steven Tadelis. 2001. Incentives versus transaction costs: A theory of procurement contracts. *The RAND Journal of Economics* 32(3): 387–407.

Benamghar, Radia, Atsushi Iimi. 2011. Efficiency in public procurement in rural road projects of Nepal. World Bank Policy Research Working Paper No.5736. The World Bank: Washington DC.

Besant-Jones, John. 2006. "Reforming Power Markets in Developing Countries: What Have We Learned?" Energy and Mining Sector Board Discussion Paper No. 19, World Bank, Washington, DC.

Chakraborty, Indranil. 2006. "Bundle and Separate Sales in Auctions with Entry." *Games and Economic Behavior* 54: 31-46.

De Silva, Dakshina, Timothy Dunne, and Georgia Kosmopoulou. 2003. An empirical analysis of entrant and incumbent bidding in road construction auctions. *The Journal of Industrial Economics* 51: 295–316.

De Silva, Dakshina, Timothy Dunne, Anuruddha Kankanamge, and Georgia Kosmopoulou. 2008. The impact of public information on bidding in highway procurement auctions. *European Economic Review* 52: 150–81.

Estache, Antonio, and Atsushi Iimi. 2009. Joint bidding, governance and public procurement costs: A case of road projects. *Annals of Public and Cooperative Economics* 80: 393–429.

Estache, Antonio, and Atsushi Iimi. 2010. Bidder asymmetry in infrastructure procurement: Are there any fringe bidders? *Review of Industrial Organization* 36: 136–87.

Estache, Antonio, and Atsushi Iimi. 2011. *The Economics of Public Infrastructure Procurement in Developing Countries: Theory and Evidence.* Center of Economic Policy Research: London.

Flyvbjerg, Bent, Mette Skamris Holm, and Søren Buhl. 2002. Underestimating costs in public works projects: Error or lie? *Journal of the American Planning Association* 68: 279-295.

Flyvbjerg, Bent, Mette Skamris Holm, Søren Buhl. 2004. What causes cost overrun in transport infrastructure project? *Transport Review*, Vol. 24, pp. 3-18.

Foster, Vivien, Cecilia Briceno-Garmendia. 2010. *Africa's Infrastructure: A Time for Transformation*. The World Bank.

Greene, William. 1997. *Econometric Analysis Third Edition*. Prentice Hall.

Guasch, Luis. 2004. *Granting and Renegotiating Infrastructure Concessions: Doing It Right*. Washington, DC: World Bank.

Gupta, Srabana. 2002. Competition and collusion in a government procurement auction market. *Atlantic Economic Journal* 30: 13–25.

Haile, P. 2001. Auctions with resale markets: An application to U.S. forest service timber sales. *The American Economic Review*, 91(3): 399-427.

Levin, Dan, and James Smith. 1994. Equilibirum auctions with entry. *The American Economic Review*, Vol. 84, No. 3. (Jun., 1994), pp. 585-599.

Li, Tong, and Isabelle Perrigne. 2003. "Timber Sale Auctions with Random Reserve Prices." *Review of Economics and Statistics* 85: 189–200.

Li, Tong, and Xiaoyong Zheng. 2006. "Entry and Competition Effects in First-Price Auctions: Theory and Evidence from Procurement Auctions. Cemmap working paper CWP13/06, University College London.

Maskin, Eric and John Riley, 2003. "Uniqueness of equilibrium in sealed high-bid auctions," *Games and Economic Behavior*, Elsevier, vol. 45(2), pages 395-409, November

McAfee, Preston, and John McMillan. 1987. Auctions with a stochastic number of bidders. *Journal of Economic Theory* 43: 1–19.

Ohashi, Hiroshi. 2009. Effects of transparency in procurement practices on government expenditure: A case study of municipal public works. *Review of Industrial Organization* 34: 26785.

Paarsch, Harry J. 1997. Deriving an estimate of the optimal reserve price: An application to British Columbian timber sales. *Journal of Econometrics*, 78(2): 333-357.

Palfrey, Thomas. 1983. "Bundling Decisions by a Multiproduct Monopolist with Incomplete Information." *Econometrica* 51: 463–83.

Plummer, Janelle, and Piers Cross. 2007. "Tackling Corruption in the Water and Sanitation Sector in Africa: Starting the Dialogue." In *The Many Faces of Corruption: Tracking Vulnerabilities at the Sector Level*, ed. Edgardo Campos and Sanjay Pradhan, 221–63. Washington, DC: World Bank.

Porter, Robert, and Douglas Zona. 1993. Detection of bid rigging in procurement auctions. *Journal of Political Economy* 101: 518–38.

Ware, Glenn, Shaun Moss, Edgardo Campos, and Gregory Noone. 2007. Corruption in public procurement: A perennial challenge. In *The Many Faces of Corruption: Tracking Vulnerabilities at the Sector Level*, ed. Edgardo Campos and Sanjay Pradhan, 295–334. Washington, DC: World Bank.

World Bank. 2008b. “Key Topics in Public Water Utility Reform.” Water Working Notes No. 17, World Bank, Washington, DC.

WSP-Africa (Water and Sanitation Program–Africa). 2005. “Rogues No More? Water Kiosk Operators Achieve Credibility in Kibera.” Field note, WSP-Africa, Nairobi.