The Effect of Price on the Quality of Public Construction in Japan

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Abstract. We examine whether the price affects the contractor's choice of quality using the ex-post quality evaluation data of public construction projects conducted by Ise City in Japan. Ise City employs a sealed-bid first-price auction with reserve and minimal prices in the selection of contractors. Upon completion of the project, Ise City evaluates the quality of the work using a 100-point scale score based on items such as administration, safety, time management, external appearance, and functionality. Our results show that the winning price in the auction does not affect the quality of the work. We discuss several reasons behind this finding.

Keywords. First-Price Auction; Minimum Price; Performance Evaluation Score; Procurement

JEL Codes. D44; H57; L52

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1 Introduction

The quality of public projects is often as important as the cost of procurement for governments, especially when the project involves construction work. In 2005, "the Act for Promoting Quality Assurance in Public Works" was enforced in Japan under the jurisdiction of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), which requires both central and municipal governments to maintain the quality of public construction projects. In response to the act, many municipal governments decided to conduct an ex-post performance evaluation for every construction project after completion.

Soon after the enforcement of this act, MLIT (2007) advocated that there is a positive correlation between the quality of public construction projects and the winning price in the procurement auction, based on their analysis of data from governmental construction projects in 2003. That is, a low winning price tends to lead to a low quality. Based on this belief, MLIT has instructed municipal governments to set a minimum price, which is the lowest acceptable price in procurement auctions, and has required an upward revision of the minimum price every few years.

In this article, we examine the existence of such correlation in a recent municipal procurement. We explore the contractor's choice of quality using the ex-post quality evaluation data of public construction projects procured by Ise City in Japan. Ise City employs a sealed-bid first-price auction with reserve and minimum prices to select the contractor for public procurement. Upon completion of the project, Ise City evaluates the quality of the work using a 100-point scale score based on items such as administration, safety, time management, external appearance, and functionality.

In our results based on the three types of estimation models, the impact of the winning price on the quality of the work is not confirmed. The results suggest that the winning price and the quality are not related to each other in Ise City's procurement.

It should be noted that the estimation results may contain a downward bias that makes the correlation between the price and the quality unclear because of the potential sample selectivity. With one exception, no projects of extremely low quality are observed in the data. Hence, it is also likely that the use of minimum prices is effective in maintaining quality.

The remainder of this paper is organized as follows. In Section 2, we review the relevant literature. In Section 3, we document the procurement process and the ex-post performance evaluation for construction projects in Ise City. In Section 4, we describe our hypothesis and a linear model used to analyze the quality choice in public construction works. In Section 5, we describe the data in detail. In Section 6, we show the estimation results, and in Section 7, we discuss several reasons behind the results and provide policy implications. We show an extra empirical model and the results in the Appendix.

2 Literature Review

The trade-off between the winning price in auction and the quality of construction work has been a major concern for decades in industrial organization. Decarolis (2014) is closely related to our study. He explores cases of Italian public procurement where average bid auctions are under replacement by first-price auctions. Average price auctions work similarly to auctions with a minimal price. He shows that the switch to the first-price auctions substantially lowers the winning price, but that it also worsens performance, especially cost overruns and time delays because contracts are not binding. He remarks that as theoretical backgrounds behind the trade-off between the winning price and the quality, adverse selection, moral hazard, and the winner's curse are all conceivable. Iimi (2013) also studies this topic and finds in procurement data of Nepal that anticipating cost overruns lowers bids in an auction, and a low winning price tends to result in time delay. While both Decarolis (2014) and Iimi (2013) consider cases of incomplete contracts and measure the project performance by using factors such as cost overruns and time delays, our study does not focus on the rigidity of contracts and it measures the quality by checking the 100-point scale score directly. Recently, Bajari et al (2016) and De Silva et al (2017) show that contractual incompleteness increases procurement costs using highway construction data. As theoretical studies on low price bidding in procurement auctions, there are Wang (2000), Calveras et al (2004) and Burguet et al (2012).

Studies of scoring auctions such as Asker and Cantillon (2008, 2010) and Lewis and Bajari (2011) are also related to this research. In deciding the contractors, scoring auctions use not only price, but also other important factors such as project period and quality. One motivation behind scoring auctions is to overcome ex-post problems such as cost overruns, time delays, and defective works. Decarolis et al (2016) empirically studies the dynamic setting of procurement where past scores about safety and quality affect the future contract awards. They find that introducing scoring auctions brings higher performance of contractors and has no effect on the contract price.

In the context of Japanese public procurement, Suzuki et al (2012) surveys that the trade-off between low winning price and quality of work has been a long-time issue. There are several papers studying relatively specific structures of Japanese procurement auctions. Ohashi (2009) studies the structural change of Japanese procurement systems from discretion to transparency in the early 2000s. Chassang and Ortner (2019) theoretically and empirically study the role of minimum price in procurement auctions and find that the minimum price can limit collusion. Ishii (2009, 2014) analyzes bidding rings with different collusive schemes in municipal procurement auctions.

3 The procurement process, ex-post evaluation, and penalty on defective works

This section overviews the procurement system and the ex-post performance evaluation in Ise City, Mie Prefecture, Japan, whose population was 127,000 as of 2016.

Ise City procures construction projects via auctions. Any firm can submit a bid through the online submission system as long as it satisfies certain requirements for each project. The city classifies the prospective firms into ranks from A to E using factors including sales, number of licensed technicians, and experience. It also assigns a rank (or ranks) to each project, so that bidders with the corresponding rank can submit a bid.

The auction format is sealed-bid first-price auction with reserve price and minimum price. Bids that are higher than the reserve price or lower than the minimum price are disqualified. The reserve price is usually revealed before the auction.[1] However, at the discretion of the city, the reserve price is sometimes disclosed only after an auction for a project whose reserve price is larger than 30 million.

The minimum price is calculated after the auction based on the submitted bids to keep it secret from bidders before the auction. The calculation of the minimum price in Ise City is rather complicated compared with other municipalities in Japan. The details of the calculation are as follows. First, bids between 0.8 and 1 of the reserve price are extracted. If the number of extracted bids is 3 or fewer, then 0.75 of the reserve price is determined as the minimum price. Otherwise, 0.95 of the average price of 4/5 from the smallest among the extracted bids is determined as the minimum price, as long as it is 0.9 of the reserve price or less. If the value is higher than 0.9 of the reserve price, then 0.9 of the reserve price is determined as the minimum price.[2]

Ise City scores each construction project on a 100-point scale that rates eight groups of evaluation items: (1) overall structure of the work, (2) sufficiency of the number of administrators and technicians, (3) administration of the process, (4) time management, (5) safety measures, (6) external affairs, (7) external appearance of the output, and (8) quality of the output. Each group has 5 to 17 detailed evaluation items, some of which can be skipped in projects with a contract price smaller than 30 million yen. A contract price is observed as the winning price in our data. The ex-post performance evaluation score is disclosed on Ise City's website for a period of two years after project completion.

The quality inspection by Ise City is more detailed if the contract price of the project is 30 million yen or higher. Additional evaluation items for such a project include daily progress recording and management, appropriate neighborhood com-

[1] In Japanese public procurement, the reserve price is determined based on the buyer's cost estimate calculated by a government engineer. Ise City does not disclose its process, however, local governments in Japan generally prepare the reserve price by rounding down some digits of the cost estimate. The buyer's cost estimates are not disclosed in Ise City, as well as most local governments in Japan.

[2] Conley and Decarolis (2016) study a procurement auction in Italy with a similar bid screening process to this, even though their focus is on collusion.

plaint handling, and extra activities for safety. Furthermore, given that a large-scale project often involves several subcontractors, monitoring and supervision of the subcontractors are evaluated and the organizational structure diagram and formal documents on the contract with the subcontractors are reviewed.

If defective work is found in a construction project, the contractor may be penalized based on Ise City's municipal bylaws. There are four types of penalties. First, for severe defects, Ise City may suspend the contractor's license to participate in auctions conducted by the city for a maximum of one year. We consider this penalty important and take it into account in the empirical model. Second, the contractor's rank may be lowered if the average of performance evaluation scores is lower than 65 points. This may result in losing opportunities to participate in auctions for projects with greater value. Third, the city may demand repairs at the contractor's expense. Fourth, the contractor must undertake additional inspections in the middle of future projects.

4 Hypothesis and methods

Our main hypothesis is that the quality is high if the contractor wins the project at a high price. We estimate a linear regression model by the ordinary least squares (OLS) and instrumental variables (IV) methods to examine the hypothesis. In the Appendix, we also examine a simultaneous equations model where the price and the quality are chosen simultaneously.

The linear model

The specification of the baseline regression model to examine the quality choice is as follows:

$$quality = \beta_0 + \beta_1 ln\_winprice + X_1'\beta_2 + \varepsilon \tag{1}$$

where *quality* is the quality of the construction work. We use the performance evaluation score as the measure of the quality.

We define *winprice* as the winning price of the auction, normalized by the reserve price. *ln_winprice* is the logarithm of *winprice*. The logarithm is employed for the following reason: Even if the winning price affects the quality of construction work, it may not be linear. If the winning price is close to the winner's own cost estimate for the project, the constructor may severely reduce the cost and lower the quality. On the other hand, if the winning price is far higher than the winner's cost estimate, the constructor may not take care of cost-cutting. The logarithm is suitable for taking into account this nonlinear relationship.

The vector of contractor and project characteristics X_1 includes the following variables: *expenalty* is the expected penalty based on the experience, which is the expected value of potential loss for the contractor in case it receives a penalty of one-year license suspension for defective work. *expenalty* for a contractor for a project is measured as the sum of the reserve prices of the Ise City auctions that the contractor participated in during one year before the project starts, multiplied by the unconditional probability of winning for the contractor during that period.

The unconditional probability of winning for a contractor in a period is calculated as the frequency of winning divided by the frequency of bidding during the period.[3] We expect that a contractor with a greater expected penalty may do higher quality work. *reserve* is the reserve price of the auction, which is a proxy of project size. *length* is the length of the project period. *backlog* is the value of backlog works, which is defined as the total amount of the contract value won by the contractor in Ise City before the auction and not completed by the auction. *sales* is the total sales amount by the contractor for a year.

X_1 also includes some dummy variables. *minprice_d* is 1 if the contract is won at the minimum price in the auction, and 0 otherwise. Dummy variables for three major project types (civil engineering, road paving, and water supply) and five major contractors are also included.

The coefficients β_1 is our main interest. We will examine our hypothesis by testing $\beta_1 = 0$ as the null hypothesis against the alternative hypothesis of $\beta_1 > 0$.

The IV method

In Equation (1), *ln_winprice* may be endogenous and the OLS estimator may be biased. One reason is that the error term includes an unobservable cost factor, which may impact both the price and the quality. Thus we employ the IV method.

In the IV model, the following two variables are used as the instrumental variables for *ln_winprice* of Equation (1): *numbid* is the number of actual bidders for each auction, and *ln_minprice* is the logarithm of *minprice*, which is the minimum price of the auction, normalized by the reserve price. As well as the winning price, we take the logarithm of *minprice*.

These variables are suitable as the instrumental variables, because the number of bidders decreases the winning price in standard auction theory and practice, and the minimal price directly limits the range of the winning price, while these do not directly affect the quality. Two-stage least squares (2SLS) is employed for the estimation. Table 1 shows all variables used in the models with brief definitions.

[**Table 1 around here**]

5 Data

We estimate the models considered in Section 4 using the data of public construction projects conducted by Ise City. We chose Ise City because it is one of a small number of local governments in Japan that publicly disclose a wide range of information related to public procurement, such as auction results, ex-post evaluation scores of construction works, and detailed information of the auction participants.

We collect data from three data sources. First, the data for the auctions and the contracts is obtained from the online procurement auction system of Ise City. This

[3] We use the data of Ise City's auctions in 2012 to construct *expenalty* for projects in 2013.

includes the contractor's identity, the winning price, the minimum price, the length of the project, the reserve price, the project type, and the number of actual bidders. Second, the data of the performance evaluation scores used as *quality* is obtained from Ise City's official website. Finally, the sales of the contractors are obtained from the Construction Industry Information Center's database. This database contains the basic data of all construction companies engaging in public construction works in Japan.

Both the data of performance evaluation scores and the auction bids are available for 352 projects, of which 133 are civil engineering, 54 are road paving, and 49 are water supply works. Both auctions and construction works in the data were completed between June 2013 and March 2015. Within this period, there was no major change in Ise City's procurement auction rules.[4]

The reserve price of the auctions is kept secret in 30 auctions but is known to the bidders in other auctions. Figure 1 shows the scatter plot of *winprice* and *quality*. As shown in the figure, *quality* distributes over a range between 70 and 94 with one exception, which is 57. *winprice* is equal to *minprice* in 25 auctions. The distribution of *minprice* is shown in Figure 2.

[**Figures 1 and 2 around here**]

For the estimation, we use three datasets: Dataset 1 includes projects with a winning price below 30 million yen. Dataset 2 is a subset of Dataset 1 such that it includes projects whose winning price is strictly higher than the minimum price. Dataset 3 includes projects whose winning price is 30 million yen or higher. We divide the data into Dataset 1 and Dataset 3 at the winning price of 30 million yen, given the fact that the quality inspection by Ise City is more detailed in the latter class of projects. We further generate Dataset 2 by excluding the projects whose winning price is truncated by the minimum price from Dataset 1. Each of Dataset 1, 2, and 3 has 288, 267, and 64 projects, respectively. Tables 2 and 3 show the descriptive statistics of the variables used in the analysis for Datasets 1 and 3, respectively.

[**Tables 2 and 3 around here**]

6 Estimation results

OLS estimation results of the linear model

Table 4 reports the OLS estimation results with robust standard errors in parentheses. Among the six columns, Columns (1), (2), and (3) show the estimation

[4]We avoid use of one project with a minimum price of 0.7, which is irregularly low.

results of Equation (1) using Datasets 1, 2, and 3, respectively. Columns (4), (5), and (6) are the results of Equation (1) dropping off several explanatory variables on Dataset 1.

[Table 4 around here]

The OLS results show, first, that *ln_winning price* is not significant in any of Columns (1), (2), and (3). Second, *ln_winning price* is positively significant only when we estimate the simple regression model using *ln_winning price* as the only explanatory variable, as shown in Column (4), which is consistent with the positive correlation claimed by MLIT (2007). However, the coefficient of *ln_winning price* dropps and becomes insgnificant after adding some control variables, as shown in Columns (5) and (6).

Among the control variables, the coefficients of *reserve* are positive and significant in every column, that is, the quality is higher in a larger project. *backlog* is positive and significant in Columns (1) and (2), which implies that a contractor with backlog works does better quality work. In Column (3), *sales* is significant, whereas *backlog* is not. The coefficients of *expenalty* and *length* are insignificant in any of Columns (1), (2), and (3).

IV-2SLS estimation results of the linear model

Table 5 reports the 2SLS estimation results using the IV method. Each of Column of (1), (2), and (3) shows the 2SLS estimation results of Equation (1), using Datasets 1, 2, and 3, respectively. The first and second subcolumns of each Column show the first and the second stage estimation results of the 2SLS, respectively.

[Table 5 around here]

In the first stage regression with *ln_winprice* as the dependent variable, *ln_minprice* is positive and significant in each of (1) to (3). *numbid* is negatively significant, which is consistent with a standard auction theory.

In the second stage regression with *quality* as the dependent variable, the results are very similar to those of the OLS. The coefficient of *ln_winprice* is insignificant, as shown in the second subcolumn of Columns (1) to (3). The coefficients of *reserve* are again positive and significant in Columns (1) to (3), and *backlog* is positive and significant in Columns (1) and (2). Sargan test statistics at the bottom of the table show that the overidentifying restriction test does not reject the null hypothesis that the instrumental variables are exogenous.

Hausman test and model specification

For model specification, we perform the Hausman test for exogeneity by comparing the 2SLS estimates of *ln_winprice* with the OLS estimates to see whether *ln_winprice* is indeed endogenous.

The Hausman test statistics using Dataset 1 is 0.59 with p-value 0.44, whereas it is 0.83 with p-value 0.36 in Dataset 2 and 1.75 with p-value 0.19 in Dataset 3. We conclude that *ln_winprice* is exogenous and the OLS result is reliable in every dataset.

In summary, a simple correlation between the quality and the winning price is observed in our data, however, the correlation is no longer significant when we control some project and bidder characteristics. The estimation results of Equation (1) are almost the same across the methods, suggesting that the winning price does not affect the quality. Moreover, the estimation result of the simultaneous equations model in the Appendix indicates that the quality does not affect the winning bid. These results suggest that quality and price are chosen separately in Ise City construction projects.

7 Policy implications and concluding remarks

Based on the empirical results in the previous section, we provide economic implications, some of which may contribute to consideration for public construction policy.

Practitioners have expressed concern that low winning prices may lead to low quality works. However, in our research, this causality is not confirmed. Why is a positive relationship between the winning price and quality suggested by MLIT (2007) not observed? There are two possible reasons.

First, bid screening based on minimum prices may distort the choices of the bids, and the distortion may make the correlation between the price and the quality unclear. In public auctions of Japan, bids are automatically screened out if the bids are lower than the minimum price. Thus, a low quality bidder would deliberately avoid bidding too low in order to avoid being screened out.

Furthermore, minimum prices in public construction auctions are gradually raised over years in response to the instruction from MLIT. The minimum prices of the auctions in MLIT (2007) are between 0.66 and 0.85, but in our data the minimum price is between 0.7 and 0.9. It is likely that the increase in the level of minimum prices restricts the trade-off between the winning price and the quality in our data.

Second, there may be a case of procurement auctions that the winning price simply does not affect the quality. Consider a contractor as a simple profit maximizer. The contractor may deliver the construction work with a quality that satisfies the minimum requirement, because the amount of transfer from the government is already determined at the auction prior to the choice of the quality, and there is no ex-post reward for delivering a high quality work.

It is difficult to evaluate the introduction of minimum price to procurement auctions, as the above two reasons present the opposite views. We can at least say that a minimum price of 0.9 as the ratio to the reserve price is too high, though a minimum price as high as such level is often used in Japanese procurement auctions. Our results show that there is not a significant effect of winning price on the quality of the work as long as the minimum price is between 0.75 and 0.9.

Besides, we leave a comment on the specific calculation of the minimum price employed by Ise City discussed in Section 3. Following this calculation, minimum price is non-linearly changed to bids or the number of bidders. For example, if there are six bidders whose bids are 0.78, 0.78, 1, 1, 1, and 1, then the minimum price is calculated as 0.9. If there are five bidders whose bids are 0.78, 0.78, 1, 1, and 1, then this slight difference substantially changes the minimum price to 0.75.[5] Because of this complicated calculation of the minimum price, bidders face a severe uncertainty. In 137 out of 382 auctions, one or more bidders are disqualified because their bids are lower than the minimum prices. More appropriate contractors for those projects may exist, and there may be a significant loss of contract fees. A simpler calculation of the minimum price is desirable.

We hope that this research will contribute to a better understanding of the recent public procurement process in Japan and encourage further studies on this topic.

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Appendix

The OLS estimator may be biased because the price and the quality can be determined simultaneously. A contractor may choose the bid and the quality of the work simultaneously before the auction, given exogenous variables such as the characteristics of the contractor and the project. After winning the auction, the contractor then implements the construction work with the planned quality.[6] In order to model this simultaneous decision, we examine the simultaneous equations model below.

The simultaneous equations model

The simultaneous equations model consists of a system of two equations that have *quality* and *ln_winprice* as the explained variables, respectively. This system is estimated using three-stage least squares (3SLS). The equation for *quality* is the same as Equation (1). The equation for *ln_winprice* is as follows:

$$ln\_winprice = \gamma_0 + \gamma_1 quality + X_2' \gamma_2 + \varepsilon_2 \tag{2}$$

X_2 includes *numbid*, *ln_minprice*, and *hidreserve_d*. *hidreserve_d* is a dummy variable that is 1 if the reserve price is kept secret from the bidders in the auction, and 0 otherwise.[7] X_2 also includes the project and contractor characteristics, such as *ln_reserve*, *length*, *backlog*, and *sales*, as well as the dummy variables for the project types and major contractors. As the winning price is of interest in many auction

[5] This example is suggested by the associate editor.

[6] Iimi (2013) observes the simultaneous decision of bids and ex-post adjustments such as cost overruns and time delays in the procurement auctions of Nepal.

[7] De Silva et al (2008) insist empirically that hiding the buyer's engineering cost estimate in auction increases procurement costs.

studies, Equation (2) may be rather familiar compared with (1). The system of Equations (1) and (2) may better represent the decision making process of the contractors than the single equation model.

3SLS estimation results of the simultaneous equations model

Table 6 reports the estimation results of the system of Equations (1) and (2) using the 3SLS. Columns (1), (2) and (3) correspond to the results using Datasets 1, 2 and 3, respectively.

[**Table 6 around here**]

In the Table, the estimation results of Equation (1) are shown in the first subcolumn in each of Columns (1) to (3). The results are similar to the OLS and IV-2SLS results: *ln_winprice* is insignificant in Columns (1) to (3). Among the control variables, *reserve* is positive and significant in Columns (1) to (3), and *backlog* is positively significant in Columns (1) and (2).

The estimation results of Equation (2) are shown in the second subcolumn in Columns (1) to (3). In contrast to our expectation, *quality* is insignificant in each of Columns (1) to (3). Among the control variables, *ln_minprice* is positively and *numbid* is negatively significant in each of (1) to (3). *sales* is positively significant in (1) and (2), whereas *backlog* and *hidreserve_d* are positively significant in (3).

For model specification, we perform the Hausman test for exogeneity of *ln_winprice*. The Hausman test statistics using Dataset 1 is 0.59 with p-value 0.44, whereas it is 0.84 with p-value 0.48 in Dataset 2 and 1.76 with p-value 0.19 in Dataset 3, suggesting that *ln_winprice* is exogenous and the OLS result is reliable in each dataset.

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Figure 1: The scatter plot of winning prices and qualities

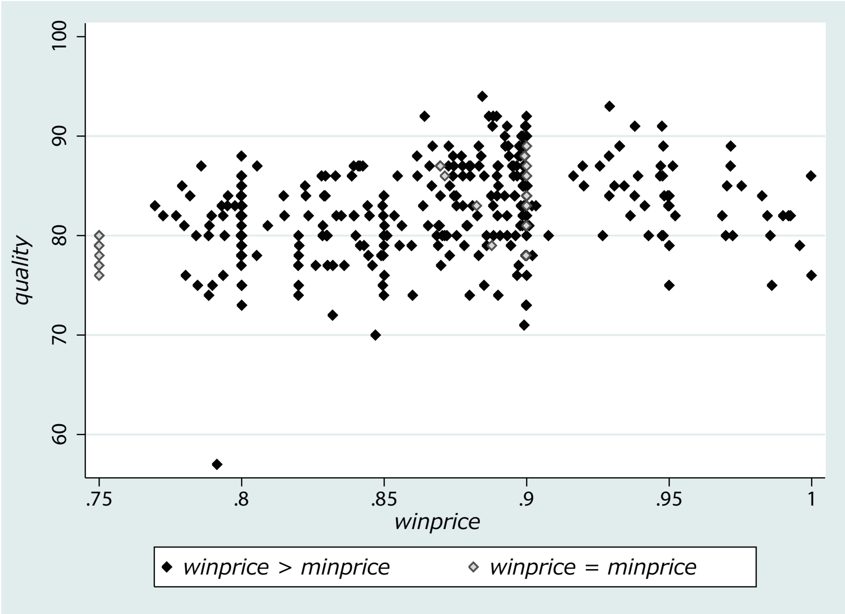

Figure 2: The distribution of minimum prices

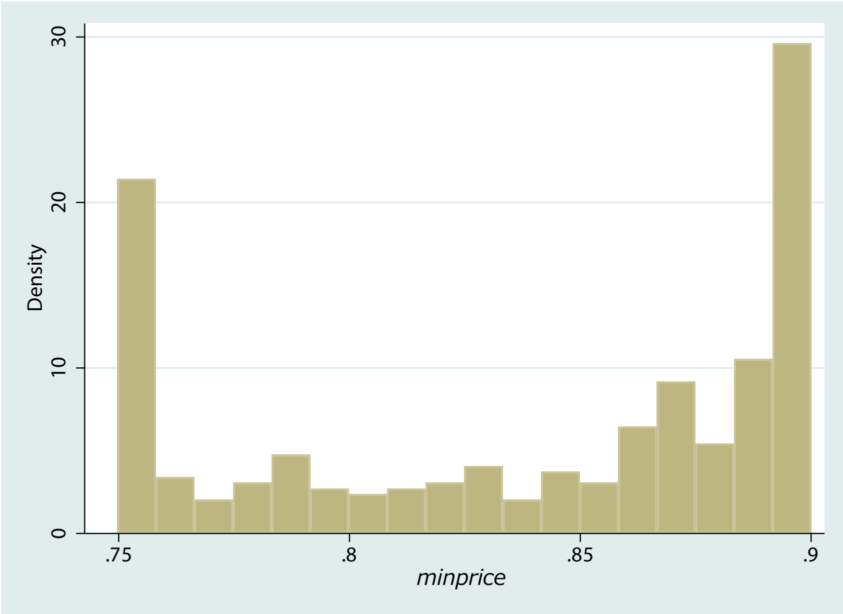

Table 1: The list of variables and brief definitions

Variable	**Brief Definition**
quality	quality of construction work
(ln_)winprice	(the logarithm of) winning price normalized by the reserve price
expenalty	expected value of the loss by the penalty
(ln_)reserve	(the logarithm of) reserve price of auction in million yen
length	length of project period
backlog	value of backlog works
sales	total sales amount by contractor for the year of 2015
numbid	the number of actual bidders
(ln_)minprice	(the logarithm of) minimum price normalized by the reserve price
minprice_d	dummy for a contract won at the minimum price
hidreserve_d	dummy for that reserve price is hidden from bidders
civileng_d	dummy for civil engineering work
roadpav_d	dummy for road paving work
watersup_d	dummy for water supply work
contractor1_d	dummy for the major contractor 1
contractor2_d	dummy for the major contractor 2
contractor3_d	dummy for the major contractor 3
contractor4_d	dummy for the major contractor 4
contractor5_d	dummy for the major contractor 5

Table 2: Summary statistics for projects with a winning price below 30 million yen

Variable	Mean	Std. Dev.	Min.	Max.	N
quality	81.764	4.288	57	92	288
winning price (in million yen)	10.613	7.375	2.202	29.8	288
winprice	0.858	0.053	0.75	1	288
ln_winprice	-0.155	0.062	-0.288	0	288
expenalty	0.079	0.089	0	0.841	288
reserve	12.262	8.333	2.753	35.92	288
ln_reserve	16.091	0.689	14.828	17.397	288
length	0.101	0.053	0.02	0.44	288
backlog	0.034	0.054	0	0.29	288
sales	0.003	0.03	0	0.49	288
numbid	12.316	8.782	1	50	288
minimum price (in million yen)	10.355	7.324	2.064	29.758	288
minprice	0.830	0.055	0.75	0.9	288
ln_minprice	-0.188	0.067	-0.288	-0.105	288
minprice_d	0.073	0.26	0	1	288
hidreserve_d	0.021	0.143	0	1	288
civileng_d	0.333	0.472	0	1	288
roadpav_d	0.177	0.382	0	1	288
watersup_d	0.146	0.354	0	1	288

TABLE 3: Summary statistics for projects with a winning price of 30 million yen or higher

Variable	Mean	Std. Dev.	Min.	Max.	N
quality	86.641	3.578	78	94	64
winning price (in million yen)	63.01	33.228	30.5	246.87	64
winprice	0.909	0.042	0.8	1	64
ln_winprice	-0.096	0.046	-0.223	0	64
expenalty	0.12	0.075	0	0.286	64
reserve	69.351	36.825	33.151	274.3	64
ln_reserve	17.956	0.425	17.317	19.43	64
length	0.207	0.084	0.077	0.528	64
backlog	0.049	0.056	0	0.199	64
sales	0.029	0.191	0	1.528	64
numbid	12.234	7.001	1	28	64
minimum price (in million yen)	60.776	33.306	25.725	246.87	64
minprice	0.872	0.051	0.75	0.9	64
ln_minprice	-0.139	0.062	-0.288	-0.105	64
minprice_d	0.063	0.244	0	1	64
hidreserve_d	0.359	0.484	0	1	64
civileng_d	0.547	0.502	0	1	64
roadpav_d	0.031	0.175	0	1	64
watersup_d	0.109	0.315	0	1	64

Table 4: The OLS estimation results of the linear model

Variable	(1) *quality*	(2) *quality*	(3) *quality*	(4) *quality*	(5) *quality*	(6) *quality*
ln_winprice	1.254	0.486	3.146	15.69**	5.313	2.396
	(3.636)	(4.150)	(6.157)	(3.956)	(3.496)	(3.413)
expenalty	6.087	7.495	-10.93			
	(4.485)	(4.120)	(8.262)			
ln_reserve	1.135**	0.997**	3.277**			1.257**
	(0.387)	(0.375)	(1.084)			(0.291)
length	-6.407	-6.534	0.0258			
	(4.977)	(4.735)	(4.757)			
backlog	13.54*	14.36*	2.594			
	(5.612)	(5.641)	(9.907)			
sales	-10.48	-12.01	1.474**			
	(9.437)	(6.714)	(0.530)			
minprice_d	0.152		-2.403			
	(0.782)		(1.474)			
civileng_d	1.487**	1.401*	4.048**		1.958**	1.583**
	(0.505)	(0.582)	(1.223)		(0.530)	(0.535)
roadpav_d	4.572**	4.368**	2.789*		6.115**	5.959**
	(0.718)	(0.689)	(1.246)		(0.637)	(0.632)
watersup_d	2.522**	2.527**	1.491		2.775**	2.474**
	(0.685)	(0.664)	(1.589)		(0.611)	(0.584)
Constant	61.63**	63.71**	26.54	84.19**	80.18**	59.73**
	(5.954)	(5.793)	(19.02)	(0.672)	(0.655)	(4.777)
Control	Yes	Yes	Yes	No	Yes	Yes
Observations	288	267	64	288	288	288
R-squared	0.421	0.404	0.512	0.051	0.346	0.381

Standard errors in parentheses

** $p<0.01$, * $p<0.05$.

"Control" row is "Yes" if dummies for major contractors are included.

Table 5: The IV-2SLS estimation results

	(1)		(2)		(3)	
	first	second	first	second	first	second
Variable	*ln_winprice*	*quality*	*ln_winprice*	*quality*	*ln_winprice*	*quality*
ln_winprice		4.800		5.771		20.54
		(5.711)		(6.901)		(14.23)
expenalty	0.0745	5.593	0.0436	7.079	0.0846	-14.82
	(0.0598)	(4.410)	(0.0649)	(4.950)	(0.123)	(8.040)
ln_reserve	-0.00371	1.119**	-0.00385	0.988*	-0.00143	3.409**
	(0.00550)	(0.377)	(0.00578)	(0.416)	(0.0159)	(0.977)
length	0.112	-7.054	0.140*	-7.741	0.0347	-0.861
	(0.0666)	(4.914)	(0.0673)	(5.258)	(0.0900)	(5.616)
backlog	0.0467	13.37*	0.0854	13.87*	0.171	0.456
	(0.0741)	(5.468)	(0.0758)	(5.857)	(0.133)	(8.465)
sales	0.190	-10.37	0.268	-12.63	-0.0393	2.224
	(0.128)	(9.188)	(0.140)	(10.58)	(0.0299)	(1.873)
minprice_d	-0.0391**	0.271			0.00275	-2.448
	(0.0102)	(0.777)			(0.0286)	(1.728)
numbid	-0.00234**		-0.00238**		-0.00284*	
	(0.000457)		(0.000465)		(0.00138)	
ln_minprice	0.710**		0.640**		0.371**	
	(0.0553)		(0.0579)		(0.106)	
hidreserve_d	0.0298		0.0326		0.0343**	
	(0.0199)		(0.0213)		(0.0120)	
civileng_d	-0.000637	1.558**	-0.00578	1.567**	-0.0189	4.740**
	(0.00773)	(0.499)	(0.00798)	(0.561)	(0.0246)	(1.288)
roadpav_d	-0.0216*	4.490**	-0.0231*	4.280**	-0.0434	3.352
	(0.00999)	(0.706)	(0.0104)	(0.759)	(0.0338)	(2.163)
watersup_d	-0.0252**	2.549**	-0.0299**	2.630**	-0.00560	1.590
	(0.00913)	(0.668)	(0.00920)	(0.716)	(0.0215)	(1.348)
Constant	0.0573	62.54**	0.0474	64.79**	-0.00796	26.17
	(0.0860)	(5.908)	(0.0905)	(6.505)	(0.280)	(16.92)
Sargan test statistics		0.321		0.618		1.020
p-value		(0.852)		(0.734)		(0.600)
Observations	288	288	267	267	64	64
R-squared		0.419		0.400		0.470

Standard errors in parentheses

** p<0.01, * p<0.05

Dummy variables for 5 major contractors are included.

Table 6: The 3SLS estimation results of the simultaneous equation model

	(1)		(2)		(3)	
Variable	*quality*	*ln_winprice*	*quality*	*ln_winprice*	*quality*	*ln_winprice*
ln_winprice	5.191		5.771		20.43	
	(5.709)		(6.901)		(14.22)	
expenalty	5.345		7.079		-14.65	
	(4.409)		(4.950)		(8.033)	
ln_reserve	1.153**	-0.0194	0.988*	-0.00958	3.406**	0.0119
	(0.377)	(0.0180)	(0.416)	(0.0121)	(0.977)	(0.0210)
length	-7.908	0.223	-7.741	0.182*	-0.841	0.0310
	(4.905)	(0.124)	(5.258)	(0.0921)	(5.616)	(0.0776)
backlog	13.18*	-0.133	13.87*	-0.000973	0.377	0.207*
	(5.467)	(0.243)	(5.857)	(0.179)	(8.463)	(0.101)
sales	-9.501	0.293*	-12.63	0.333**	2.222	-0.0321
	(9.183)	(0.122)	(10.58)	(0.0962)	(1.873)	(0.0300)
minprice_d	-1.295*				-2.488	
	(0.555)				(1.727)	
quality		0.0135		0.00600		-0.00389
		(0.0129)		(0.00866)		(0.00659)
numbid		-0.00215**		-0.00230**		-0.00311**
		(0.000533)		(0.000491)		(0.00115)
ln_minprice		0.658**		0.618**		0.423**
		(0.0926)		(0.0718)		(0.104)
hidreserve_d		0.0247		0.0309		0.0359**
		(0.0194)		(0.0206)		(0.0103)
civileng_d	1.545**	-0.0213	1.567**	-0.0149	4.719**	0.000802
	(0.499)	(0.0244)	(0.561)	(0.0171)	(1.288)	(0.0285)
roadpav_d	4.486**	-0.0804	4.280**	-0.0480	3.341	-0.0330
	(0.706)	(0.0610)	(0.759)	(0.0398)	(2.163)	(0.0335)
watersup_d	2.538**	-0.0574	2.630**	-0.0446	1.581	0.00172
	(0.668)	(0.0349)	(0.716)	(0.0240)	(1.348)	(0.0208)
Constant	62.28**	-0.783	64.79**	-0.344	26.21	0.0954
	(5.907)	(0.787)	(6.505)	(0.540)	(16.92)	(0.349)
Observations	288	288	267	267	64	64
R-squared	0.410	-0.020	0.400	0.355	0.471	0.397

Standard errors in parentheses
** p<0.01, * p<0.05
Dummy variables for 5 major contractors are included.