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# Essays on Collusion and Competition in Multi-Attribute Procurement Auctions in Korea

다차원 공공입찰에서의 담합과 경쟁에 대한 연구

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경제학부 경제학 전공

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# Essays on Collusion and Competition in Multi-Attribute Procurement Auctions in Korea

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**Abstract**

This thesis investigates bidding behavior in the context of multi-attribute reverse auctions. Specifically, we study the manner in which construction firms tender for public-sector projects in Korea. Although the primary objective of public procurement is to achieve the best value for money, tendering often results in suboptimal award of contracts. We simulate the counterfactual scenario of such situations using a two-stage forecasting method and estimate the potential additional cost paid by the buyer.

The first chapter examines the effect of bid rigging on contract price. In the damage assessment of the 102 cases of collusion, we find that the government suffers an average overcharge of 7.78%. When the cases are broken down by the type of collusion, namely, price fixing, cover bidding, and market division, we find that the overcharge is generally higher when the collusion scheme spans over multiple projects.

The second chapter investigates the role and impact of a minimum score discrimination (MSD) rule in public procurement. To our knowledge, this study is the first to address the effect of MSD on tendering outcomes. We find that that the discriminatory scoring system leads to an average increase in procurement cost of 9.86%. Further research is needed to provide a theoretical framework and to conduct a comprehensive cost-benefit analysis of different types of MSD rules.

**Keywords:** reverse auction, procurement, construction, design-build, collusion, bid-rigging, scoring rule, MSD rule

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# 1. The Harm of Bid Rigging in Multi-Attribute Procurement Auctions

## 1.1 Introduction

Public procurement is the key mechanism through which a government initiates complex, large-scale projects and contributes value to society. The global public procurement market is worth almost $10 trillion USD per annum, which accounts for 15-20% of global GDP (World Bank, 2020). The magnitude of the market reveals the importance of ensuring efficient and cost-effective operation and fair competition in the tendering process. Procurement agencies and antitrust authorities implement various tools to detect and deter unlawful bidding arrangements in public procurement auctions. The primary method of detection is investigating reports submitted to them and offering leniency to whom that come forward with valuable information.[1] Empirical and behavioral screening techniques are also used to identify market traits and firm behavior related to cartels and collusion. One important aspect of deterring anticompetitive conduct is to impose appropriate penalties and remedies. In Korea, the Korea Fair Trade Commission (KFTC) has the authority to order corrective measures and to refer the case to the Prosecutor's Office for criminal prosecution.[2] The KFTC places a high priority to enforcement against collusive tendering: in 2018, the KFTC detected 157 cartel cases, 138 of which were related to bid

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[1] Leniency programs provide rewards and amnesty to firms that self-report and cooperate with the authorities. Ex-ante leniency encourages firms to whistleblow on their anticompetitive conduct before an investigation starts, while ex-post leniency encourages them to provide information during an ongoing investigation.

[2] Currently, the KFTC has the exclusive right to refer any competition law violations to the Prosecutor's Office. There is an amendment bill on the way to abolish this authority and enable the Prosecutor's Office to initiate its own investigations and allow others to file complaints directly. In Korea, cartels are not per se illegal; to be unlawful, it must be proved that the collusive conduct unfairly restricts competition. Private parties can also bring civil damage claims against the bid riggers, although observed less frequently and usually occur in countries with a powerful system of private enforcement such as the U.S. In the U.S., the competition law views hard-core collusive activities as per se illegal under the Sherman Act. The Department of Justice (DOJ) Antitrust Division and the Federal Trade Commission (FTC) both have the authority to initiate civil investigations and seek monetary relief.

rigging. It ultimately issued a corrective order on 135 cases, imposed penalty surcharges on 94 cases (total fines add up to 238 billion KRW), and referred 44 cases to the Prosecutor's Office (KFTC, 2019).

Such high legal risk of collusion demonstrates the need to understand and quantify the harm of bid rigging in public procurement. Yet, empirical research on the matter is limited in the literature. One reason is the lack of rich and comprehensive dataset. Another reason is the difficulty in estimating the counterfactual—the but-for price if there were no bid rigging. To estimate the effect of collusion on the winning bid, one must compare what actually happened and what would have happened in the absence of collusion. One method often used for damage assessment is the forecasting approach, which first uses a sample of non-collusive auctions to establish the relationship between contract price and its determinants and then uses the estimated model to predict the counterfactual price of collusion. The problem is, a collusive agreement can distort price as well as non-price outcomes of an auction. We are particularly concerned about the effect of collusion on a bidder's entry decision and quality competition in multi-criteria procurement auctions. We thus propose in this study a two-stage forecasting method to simulate the counterfactual scenario of bid rigging. Specifically, in the first stage, we use observations of non-collusive auctions to derive the underlying equation of number of bidders and winner's quality advantage[3]; then, we predict the expected outcomes of the two variables if there were no bid rigging for collusive auctions. In the second stage, we estimate the price equation using non-collusive auctions, and we substitute the estimates from the first stage for the actual values when estimating the hypothetical competitive price of collusive auctions. We perform damage assessment for the 102 cases of bid rigging and find that the government pays a price overcharge of 7.78% on average. When these cases are organized by the type of collusion, we find that bid riggers generally charge a higher price when the plot stretches over multiple projects. These results indicate that antitrust authorities should pay close attention to the type of bid rigging and the ability and incentives of conspirators when quantifying damage to competition.

[3] We coin the term quality advantage to describe winner's quality score relative to those of losers. See footnote 29 for its exact definition.

This paper is organized as follows. The rest of this section provides an overview of Korea's public procurement system. Section 2 gives a brief literature review on scoring auctions and on collusion in procurement. Section 3 presents the sets of data used to build the model. Section 4 establishes the model, and Section 5 discusses the results and implications. Section 6 concludes.

### *1.1.1 Korea's public procurement system*

Delivery methods

The traditional contract method in public procurement is Design-Bid-Build (hereafter, DBB), in which the owner first hires an architect for the design of the project and then separately contracts with a constructor to perform construction work. In DBB, there is a clear separation of roles and responsibilities between parties—the constructor bears the direct costs of construction, whereas the owner is accountable for any design consequences and risks associated with the project. Recently, the popularity of the DBB method has been declining especially for large, complex projects because the split responsibilities between parties can create conflicts of interest and delays in schedule. The lack of involvement of the builder during the design phase makes it difficult for the parties to evaluate constructability of the design, compare planned costs with actual costs, and issue change orders or renegotiate contract provisions if disputes arise. Hence, delivery methods that emphasize integration between design and construction are being increasingly accepted as viable alternatives to DBB. We are particularly interested in the following three methods:

(a) Design-Build (hereafter, DB)
(b) Alternative Bid (hereafter, AB)
(c) Technical Proposal (hereafter, TP)

Through these methods, the owner partially passes on the responsibility and risks associated with the project to the contractor. In general, the design phase consists of five stages: (1) pre-design, (2) schematic design, (3) design development, (4) construction document, and (5) construction administration. In a DB project, which is locally known as a *turnkey* project in Korea, the owner provides only preliminary design ((2) or (3)) and chooses a single contractor to manage the remaining design and construction processes.[4] As the design-builder is the sole responsible entity for project delivery, it has better control over the quality, performance, technology, and schedule of the project.[5] The other two delivery methods are similar to DB but different in what is expected to be submitted by bidders. In the case of AB, the owner provides construction documents, and bidders have a choice of either submitting a price bid for the original design or proposing their own design solution and price. In TP projects, the owner provides preliminary design documents, and bidders propose alternative technologies and design specifications that can enhance creativity and improve construction productivity. A relatively small number of firms are capable of competing for these types of project because they are required to maintain in-house the design, engineering, and construction skills necessary to plan and execute a work. As a concentrated market is more vulnerable to coordinated conduct, greater oversight and transparency are necessary for the procurement of these projects.

Award algorithms

For one-dimensional procurement auctions, the primary winner selection algorithm is the lowest-bid criterion. That is, the bidder quoting the lowest price is selected as the winner. This is the case for the majority of DBB projects, where a bidder is expected to submit a single price bid based on the design documents prepared by the owner. For alternative delivery methods, a bidder is required to submit a two-dimensional bid that includes a price proposal as well as a design proposal. In this study, we are interested in the following award mechanisms that consider non-price information in the bid evaluation process:

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[4] In a typical *turnkey* project, the owner provides the schematic design and instructions to tenderers, on the basis of which the bidders submit a more refined design development document. Only the winner of the procurement auction is responsible to prepare construction documents that are ready for construction. There is a less commonly used delivery method called *semi-turnkey*, in which the owner provides the design development documents and the bidders submit construction documents.

[5] Since the owner has limited involvement and the DB contractor has discretion as to the means of achieving the goal, the contractor may have competing interests and do not act for the benefit of the owner. For example, once the project is awarded, the contractor may have an incentive to choose the lowest-cost subcontractor and compromise on the quality of the project in order to maximize its own profit. Such agency problem is a crucial research question but is beyond the scope of this study.

(a) Weighted Criteria
(b) Adjusted Design Score
(c) Adjusted Price

These three methods award a contract to the bid that achieves the highest overall score of price and quality. The quality score for a design proposal is typically calculated as the weighted sum of technical scores on each design criterion. Under Adjusted Design Score, the total score of a bid is determined by a formula such as $TS = q/p$, where $p$ is price bid and $q$ is quality score.[6] The Weighted Criteria method uses a formula such as $TS = w^p p^s + w^q q$, where $w^p$ and $w^q$ are weights that add up to one and $p^s$ is price score that is decreasing in price (i.e., the lower the price, the higher the price score). These scoring rules are shaped such that they reflect the preferences of the owner, generally favoring an offer of high-quality and low-price. That being said, there can be a positive feedback between price and quality bids submitted because high-quality design is likely to involve a higher cost of production and complex technology while a low-price option is likely associated with a suboptimal quality design. Consequently, the owner is responsible to assess the relative importance of its two goals—high quality versus low price—when designing the evaluation system and the award algorithm. Table 1 summarizes the scoring rules and delivery methods that are considered in the present study.[7]

The most widely implemented approach in Korea is the Weighted Criteria algorithm. Typically, the price score is calculated by normalizing the price bid against a reference point, generally the lowest price bid, $p^s = (p_{min}/p) * 100$. Note that, unlike Adjusted Design Score or Adjusted Price, the scoring of one's bid depends on the attributes of other bids under Weighted Criteria.[8] The lowest-price bidder receives full marks, but the price score of other bidders is determined by how far away they are from the minimum price bid. With such interdependency, it is difficult to determine a bidder's optimal bidding

[6] Adjusted Price algorithm is the reciprocal of this method.
[7] There is another award method known as "Meets Technical Criteria/Low-Bid", which awards the contract to the lowest-bid seller as long as it exceeds the quality score threshold. This is equivalent to a price-only auction with a baseline design standard, where a project owner is looking for the most cost-effective offer.
[8] A scoring rule is termed interdependent if a bidder's score depends on the attributes of other bids submitted and termed independent if the score is only conditional on its own price and quality.

behavior and predict its final score. For this reason, there are only a few studies that analyze the mechanism of an auction adopting an interdependent scoring rule (Kang, 2019; Albano et al., 2008). In Korea, there is a special scoring rule used in the procurement market called a minimum score discrimination (hereafter, MSD) rule, which creates a score interdependency in the quality dimension as well. Under a typical MSD rule, the highest-quality bidder receives its own quality score, but the quality score of other bidders depends on how far apart they are from the next higher ranked quality bid. That is, the quality score of non-best designers is adjusted downward when the (absolute or percentage) difference between adjacent scores is less than a pre-announced threshold value. The MSD rule discriminates against weak bidders (with low-quality design) in favor of stronger bidders (with high-quality design), putting greater emphasis on the technical aspect of the project. Although the rule is implemented commonly in Korea, to our knowledge, no previous study has examined its role and impact on the procurement process, neither empirically nor theoretically. This topic will be discussed in more detail in the next chapter.

Table 1. Award algorithm and delivery methods

| | Design-Build | Technical Proposal | Alternative Bid |
|---|---|---|---|
| Adjusted Design Score $\left(TS = \frac{q}{p}\right)$ | award to highest-score bidder $TS_{max}$ | award to highest-score bidder $TS_{max}$ | award to highest-score bidder $TS_{max}$ when $q \geq q^o$ and $p \leq p^o$ |
| Adjusted Price $\left(TS = \frac{p}{q}\right)$ | award to lowest-score bidder $TS_{min}$ | award to lowest-score bidder $TS_{min}$ | award to lowest-score bidder $TS_{min}$ when $q \geq q^o$ and $p \leq p^o$ |
| Weighted Criteria $\left(TS = w^p p^s + w^q q\right)$ | award to highest-score bidder $TS_{max}$ | award to highest-score bidder $TS_{max}$ | award to highest-score bidder $TS_{max}$ when $q \geq q^o$ and $p \leq p^o$ |

*Note.* Under AB, the price-quality combination $(p^o, q^o)$ refers to the original design specification and cost estimate announced by the procuring entity.

### *1.1.2 Bid rigging*

The main interest of the owner is to select a contractor that can deliver the best value for money. Yet, collusive tendering undermines the owner's goal to achieve cost effectiveness and high quality. We encounter three forms of collusion in a procurement auction: fixing of price, fixing of quality, or fixing of both. One price fixing scheme frequently observed in construction tenders is when bidders agree to submit similar price bids and compete only in terms of design (Type I). There are variations in how bid riggers choose a target price and reward one another for engaging in the scheme (such as paying a "consolation prize" to losers), but it typically eliminates price competition and simplifies the bi-dimensional auction into a quality-only auction.[9] In most cases, the bidder who places the highest quality bid is awarded the contract, but as the contract price is decided endogenously, it can lead to suboptimal wealth transfer from the owner to the colluding party. Bidders can also conspire to distort competition in design, for example, by having arrangements on their design plans and specifications (Type II). If all bidders develop their design given a fixed level of overall quality, the auction becomes a price-only auction where the lowest-price bidder wins. Although the owner may accomplish the financial goal of reducing cost, this scheme could produce suboptimal design quality.

Often times, bidders coordinate their bids in terms of both price and quality. In many cases, bidders submit uncompetitive bids that are intended to be unsuccessful. This is called cover bidding—also known as shadow, complementary, or courtesy bidding—as a non-serious bidder intentionally places a phony bid so that a designated bidder becomes the winner (Type III). The bidders that are assigned to lose typically receive in exchange side payments that are large enough to cover their design cost and auction participation cost; they may be even granted an agreement in another project to serve as a subcontractor,

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[9] There are special arrangements to promote contractors of different sizes and costs to engage in the scheme. In some cases, a conspirator that appears less likely to win the auction gets to bid with a "price handicap" and receives preferential treatment compared to others. For example, a bidder with a handicap of 2% can bid 2% lower than the predetermined price that other bidders are bound to comply with. This establishes a level playing field between bidders with different cost efficiency.
In some cases, conspirators agree that the bidder that wins the auction pays a "consolation prize" to the losers. The consolation prize can be a side payment that can cover their design and participation costs or even a promise to jointly form a consortium in another project. For example, Winner A could compensate Loser B by signing a service contract with the design subcontractor of Loser B.

be the designated winner, or be part of the winning consortium. When multiple related projects are to be procured, simultaneously or over time, bidders can engage in market allocation schemes, in which they agree to divide work among themselves and avoid actively competing in projects not allocated to oneself (Type IV). The members of the ring can bring in complementary bidders independently or take turns to serve as one (also known as bid rotation).[10] Note that in (III) and (IV), competition is completely undermined. Bidder participation and bid submissions only provide false information, and the designated winner can win with any combination of price and quality in its best interest. All of these schemes can create extra cost to procurement and hinder design efficiency and innovation. There are other bid rigging mechanisms, such as bid suppression and horizontal subcontracting, but the present study focuses on the aforementioned types and definition. Table 2 summarizes the types of collusion and bidding strategy that may be used by bid riggers and the potential harm that it may cause to procurement.

Table 2. Types of bid rigging

| Type | Potential strategy | Result | Potential harm |
|---|---|---|---|
| Price fixing (I) | Fix price to the highest level and propose best design | Quality competition exists; highest-quality bidder wins | Excessive wealth transfer from owner to contractor |
| Design distortion (II) | Fix quality to the lowest level and submit cheapest price | Price competition exists; lowest-price bidder wins | Suboptimal project design |
| Cover bidding (III) | Designated winner wins with a low-quality, high-price combination | No fair competition exists | Excessive wealth transfer & suboptimal design |
| Market division (IV) | Designated winner wins with a low-quality, high-price combination | No fair competition exists | Excessive wealth transfer & suboptimal design |

[10] In the Incheon Metro case, the KFTC document specifically names the pairs of bidders that engaged in bid rotation. Also in the Four major rivers project, there are cases where a member of the bidding ring who is the designated winner in one lot serves as a complementary bidder for another member in a different lot.

## 1.2 Literature Review

### *1.2.1 Scoring auctions*

The present study is related to the literature of scoring auctions, in which bidders submit a multi-attribute bid consisting of monetary and non-monetary components. As mentioned in the previous section, various forms of scoring auctions are used for procurement, but most theoretical studies are focused on independent scoring rules that are linear in price (Che, 1993; Asker and Cantillon, 2008, 2010; Hanazono et al., 2015; Takahashi, 2018; Dastidar 2014; Huang, 2015). The seminal paper of Che (1993) shows that the optimal mechanism can be implemented by a scoring auction with a quasilinear scoring rule, and Asker and Cantillon (2008, 2010) generalize this to the case where quality and bidder types are multi-dimensional.[11] There are studies on non-quasilinear scoring rules (Hanazono et al., 2015; Takahashi, 2018), but only a few studies cope with interdependent scoring rules such as Weighted Criteria, which is the most widely used approach in Korea and the key subject of this study.

The rest of the section describes a simple model of scoring auction based on Che (1993). Consider a reverse auction for an indivisible object that consists of one buyer and $N$ potential risk-neutral sellers:

- Owner (buyer): The buyer publicly announces a scoring rule $S(p,q)\colon \mathbb{R}_+^2 \rightarrow \mathbb{R}$ that ranks different price-quality combinations. An object of quality $q$ generates a monetary value $V(q)$ to the buyer. We assume that $V' > 0$, $V'' < 0$, $\lim_{q\rightarrow 0} V'(q) = \infty$, and $\lim_{q\rightarrow\infty} V'(q) = 0$ for an interior solution.
- Bidders (sellers): A bidder $i$ submits a multi-attribute sealed bid, comprising price $p$ and quality $q$ that is verifiable and contractible. Suppose an inefficiency parameter $\theta$ is drawn i.i.d. from a distribution function $F$ with support $[\underline{\theta},\overline{\theta}]$, which has a continuously differentiable density function $f$. A bidder learns its $\theta$ as private

[11] These works extend the revenue equivalence theorem (Myerson, 1981; Riley and Samuelson, 1981) to a multi-attribute reverse auction setting and have opened a new strand of research in the auction literature.

information and faces a cost function $c(q,\theta)$. Assume that cost is increasing and convex in quality, $c_q \geq 0$ and $c_{qq} > 0$, an efficient bidder can generate the same $q$ at a lower cost, $c_\theta > 0$, and the marginal cost is increasing in $\theta$, $c_{q\theta} > 0$. A bidder's expected payoff is given by $\big(p - c(q,\theta)\big)\Pr\big(Win \big| S(p,q)\big)$, that is, the markup times the probability that it wins. Losers receive a zero payoff.

Suppose that, as in Che (1993), the scoring rule is quasilinear, $S(p,q) = V(q) - p$. Further, assume that $\mathrm{c}(q,\theta) + \frac{F(\theta)}{f(\theta)} c_{q\theta}(q,\theta)$ is non-decreasing in $\theta$ and that the trade always takes place. Che (1993) shows that in the optimal mechanism, the bidder with the lowest $\theta$ is awarded the contract. The winner chooses $q_0$ that maximizes $V(q) - J(q,\theta)$, where $J(q,\theta) = c(q,\theta) + \frac{F(\theta)}{f(\theta)} c_\theta(q,\theta)$. Note that the owner discriminates against quality compared to its true preference; the term on the right internalizes the information rents accruing to efficient bidders. There is a symmetric Bayesian Nash equilibrium where a bidder of type $\theta$ submits $q^*(\theta) = \underset{q}{\operatorname{argmax}}\ V(q) - c(q,\theta)$ and $p^*(\theta) = c(q,\theta) + \int_\theta^{\bar{\theta}} c_\theta(q,t)\left(\frac{1-F(t)}{1-F(\theta)}\right)^{N-1} dt$, and the bidder that offers the highest quality bid wins the auction.

Note that Che (1993)'s model depends on the regularity assumptions, which result in the optimal quality monotonically decreasing in $\theta$, and the assumption that bidders are symmetric, that is, their private information are identically distributed. If we relax these conditions, the most efficient bidder may not be the winner in the equilibrium (Huang, 2015; Takahashi, 2018). The analysis becomes even more complex when we consider non-quasilinear scoring rules.[12] An interdependent scoring rule such as Weighted Criteria creates interdependency across bids such that it makes it difficult for a bidder to determine its optimal strategy. To our knowledge, there is only one study that analyzes the

[12] There are independent, non-quasilinear scoring rules such as the price-over-quality ratio (hereafter, PQR) rule and the quality-over-price ratio (hereafter, QPR) rule. A PQR rule can be expressed as $S(p,q) = p/\,V(q)$. The Adjusted Price award algorithm discussed above is one example, where the bidder with the lowest price per quality score wins the auction. On the other hand, a QPR scoring rule can be expressed as $S(p,q) = V(q)/p$, analogous to the Adjusted Design Score algorithm, under which the bidder with the highest quality per price score is awarded the contract.

equilibrium properties of a scoring auction that adopts Weighted Criteria (Kang, 2019).[13] The lack of economic theory involving interdependent scoring rules calls for caution in its usage in practice, and further research seems necessary to gain a clearer understanding of bidding behavior under such rule.

### *1.2.2 Collusion in procurement auctions*

We review empirical studies that examine collusive behavior in public procurement. By and large, previous studies are concerned with price-only auctions and address the problem of collusion detection (Bajari and Ye, 2003; Porter and Zona, 1993, 1999). Porter and Zona (1999) analyze Ohio school milk auctions between 1980-1990 and estimate the reduced-form price equation of colluding (i.e., defendants of Ohio v. Trauth (1994)) and non-colluding firms, revealing that the defendants' bidding behavior was systematically different from that of the control group. Bajari and Ye (2003) expand on this analysis and develop statistical tests that can be used to screen for collusion. They investigate highway construction projects in the Midwest between 1994-1998 using both reduced-form and structural models and find that most contracts in the dataset are consistent with competitive behavior, satisfying both conditional independence and exchangeability conditions that are necessary and sufficient for competitive bidding.

The actual quantification of the harm caused by collusion is less prevalent in the literature and reports a wide range of values. Both reduced-form and structural models are used for damage assessment. As for the structural approach, there are a few recent works such as Zona (2010) and Gabrielli and Willington (2019) that estimate collusion overcharge by describing structural models of pricing behavior in first-price auctions (Lewis and Bajari, 2011; Nakabayashi and Hirose, 2013; Huang, 2015). Yet, as the present study copes with multi-attribute procurement auctions with an interdependent scoring rule,

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[13] Kang (2019) derives the equilibrium of the following extreme cases: (i) bidders fix price and only compete in terms of quality, (ii) bidders fix quality and only compete in terms of price, and (iii) a hybrid of the two scenarios. It shows that when quality weight or estimated price is high (low), or when firms that are efficient (inefficient) are more likely to enter, bidders are inclined to fix price (quality) close to the highest (lowest) acceptable level and only compete in terms of quality (price) according to bidder's type.

we cannot model equilibrium bidding behavior and specify functional forms of demand and cost. The reduced-form approach is based on strong modeling assumptions but has the benefits of simple calibration and straightforward interpretation. Some of the reduced-form methods used for damage assessment are dummy variable approach, difference-in-differences (hereafter, DID) approach, and forecasting approach. The first method estimates the price equation using pooled data and includes an indicator variable to isolate the effect of bid rigging (Laitenberger and Smuda, 2015; Notaro, 2014; Boshoff, 2015; Lee et al., 2017). Yet, this method depends on the assumption that except for the existence of collusion, the relationship between price and its determinants is identical across regimes. We can include interaction terms to allow for changes in slope coefficients, but overfitting could reduce degrees of freedom and lead to problems of multicollinearity. The DID method isolates the effect of collusion by comparing the price difference of treated and control groups between pre- and post-cartel periods (Boshoff, 2015; Laitenberger and Smuda, 2015; Kamita, 2010; Coatney and Tack, 2014). It is equally unsuitable to use this approach in the present study because it also depends on the assumption that prices of the two groups follow the same trend in the absence of collusion and requires there is a clear separation between pre- and post-cartel phases.

That being said, we use the forecasting approach to simulate the counterfactual scenario of bid rigging (Notaro, 2014; Boshoff, 2015; Lee and Hahn, 2002). As this method relaxes the coefficient equality assumption, it can give a less biased prediction than the other methods. In Korea, Lee and Hahn (2002) use the forecasting method to analyze public procurement auctions between 1995-2000 and find that the price overcharge due to collusion is around 15%. Yet, they consider all projects with budget over 10 billion KRW and the research is conducted almost two decades ago, so there is a need to bring it up to date and re-estimate the relationship for multi-criteria auctions. Lee et al. (2017) carry out a task similar to the one this study attempts, expanding the period of analysis to 2007-2016 and focusing on multi-attribute procurement auctions, and introduce additional predictors such as winner's relative quality score (which is used in this study as well) in the regression model.[14] They use the dummy variable method and find that there is a 2.7-5.6% increase in contract price in the 107 cases of collusion. The present study is closely related to these works, but we make some modifications to the methodology. In particular, we raise a concern that a collusive agreement can affect not only contract price but also bidders' entry decision and quality competition. If so, it is inappropriate to use the observed number of bidders and the observed relative quality score of collusive tendering in the estimation of counterfactual price, as done in previous studies. We thus introduce a two-stage forecasting method that can account for the missing data of such variables in the counterfactual situation. To be specific, before modeling pricing behavior, we run separate regressions to determine the number of bidders and the winner's quality advantage expected to occur if there were no collusion, and we substitute actual values by these estimates when estimating the counterfactual price. We believe that our two-stage forecasting method allows us to condition the model on more reliable data and to consider new variables such as bidder ability in the analysis, which can improve the construction of counterfactual scenario and the predictability of the model.

## 1.3 Data

<u>Auction and bidder data</u>

We obtain data on multi-attribute public procurement auctions in Korea from the Construction Association of Korea (CAK). The dataset contains detailed descriptions of about 700 procurement auctions conducted between 2008-2018. We also collect procurement data from the KONEPS database provided by the Public Procurement Service (PPS). Two sets of data are retrieved: (i) procurement auctions for public DB, TP, and AB projects conducted between 2007-2020; and (ii) procurement auctions for any public

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[14] In Lee et al. (2017), independent variables include the natural log of estimated price, number of bidders, relative quality score, winner's headquarters, CBSI, year dummies, delivery method dummies, algorithm type dummies, and construction type dummies. There are four types of relative quality score variables: (1) the difference between the winner's quality score and the average quality score; (2) the winner's quality score standardized by the average quality score; (3) the difference between the winner's and runner-up's quality scores; (4) the difference between the winner's and runner-up's quality scores multiplied by the weight on quality.

construction projects with budget over 10 billion KRW conducted between 1997-2020. The second set of data (3,002 observations) will be used to assess past experience and performance of construction firms (i.e., their number and size of past projects completed successfully). The first set of data is combined with the auction data provided by the CAK to be used for our main analysis. The combined sample includes 821 observations between 2007-2020, of which 110 cases are matched with the collusion data. To simplify the analysis, we restrict the sample to projects in the field of (i) civil engineering, (ii) architecture, and (iii) industrial equipment.[15] We also eliminate observations in which the winner submits a price bid exceeding the estimated price (i.e., the engineer's estimate for a project) or when a non-highest scoring firm is awarded the contract.[16] Lastly, we restrict our attention to non-MSD auctions, because otherwise bidders could alter their bidding strategy according to the definition and intensity of the rule. Since such data is unavailable, we proxy it by the integerness of the minimum difference (or percentage difference) between quality scores.[17] We check both ratings reported by the CAK and the PPS in case one records scores post-adjustment and the other does not. Finally, there remain 593 observations, of which 492 projects are considered collusion-free.

For each bidder participating in the 593 projects, we collect its workload data from the DART database provided by the Financial Supervisory Service (FSS). A bidder's backlog measures the value of unfinished work during the quarter of a given project. We expect that a contractor that has a heavy workload faces higher opportunity costs to participate in another tender and thus would bid more cautiously (i.e. higher price) (Porter and Zona, 1993). Note that the maximum value of backlog amounts during the sample

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[15] Observations of other fields of public work, such as landscaping and information & communication technologies, are excluded due to low number of observations. The field of architecture is subdivided into residential and non-residential, and the field of civil engineering is subdivided into transport infrastructure, waterworks, and others (Presidential Decree No. 31380). The field of industrial (& environmental) equipment includes waste treatment plants and environmental facilities. These categories are used to evaluate constructors' experience and performance on similar projects during the PQ procedure.

[16] For instance, an alternate bidder may be awarded the contract when the highest-score bidder is disqualified for submitting a price bid that exceeds the projected price.

[17] To be specific, we examine the quality score difference between 3%-15% that is a whole number. In most cases, the quality scores are discriminated by 5%, 7%, 10%, or 15%.

period represents a firm's production capacity. We define a backlog ratio as the ratio of a bidder's current backlog to its capacity (i.e., capacity utilization rate).

We also collect data on the bidders' execution capacity and performance record from the database provided by the CAK.[18] A contractor's execution capacity is appraised and announced publicly on an annual basis at the end of July by the Minister of Land, Infrastructure and Transport (MOLIT).[19] It is calculated for each field in which the company holds a construction license[20], taking into account factors such as its total construction performance over the past three years, financial stability (e.g., working capital and profit margin), technical competence (e.g., experience of staff, productivity of staff, and R&D investment), and other indicators (e.g., innovation effort, safety and environmental management, and quality control). We find this variable to be a key determinant of a bidder's technical qualification and capability, as we expect that a firm with high execution capacity to be more skilled, experienced, and informed about the needs of the buyer. Another important indicator of a contractor's ability is its experience and performance on similar projects. The CAK reports the amount of construction work a firm has executed (i.e., total construction cost) annually for different types of construction projects.[21] This value can imply a firm's areas of expertise and potential improvement over

[18] The database only reports information between 2004-2020 on construction companies that are licensed and currently operating. We obtained the annually published CAK member directory between 2010-2020 to collect performance data on companies that went out of business or have missing information on the database (17 out of 105).

[19] The MOLIT consigns the assessment of the execution capacity of construction firms to the CAK. The execution capacity data is available on the CAK website (http://www.cak.or.kr/) and the Knowledge Information System of Construction Industry (KISCON), which provides comprehensive information about the construction sector to the public.

[20] A construction company can be certified and registered with the CAK for civil engineering and building works, or separately for (i) civil engineering and (ii) civil building. There is also a distinct license for (iii) industrial equipment and (iv) landscaping. A company with a license in civil engineering and building works is able to partake in construction of (i) and (ii) projects, but the reciprocal is not true.

[21] The performance data is provided for the following types of construction:

- Civil engineering: roads/bridges, dams, harbors, airport, railway/subway, riverwork/forestry/agricultural engineering, water supply/sewage, other works
- Architecture: residential, commercial, mining/factory, educational, traditional architecture, other works
- Industrial (& environmental) equipment: industrial production facility, power plant, incineration plant, sewage and wastewater treatment plant, energy storage and supply facility, other works

time. We should note that these information are actually used by practitioners to evaluate contractors and subcontractors during the prequalification (PQ) phase (see Appendix 1.A for the process of a typical DB auction).[22] PQ applicants are assessed based on criteria such as their past performance, technical capability, execution capacity, and trustworthiness (i.e., cooperation with local companies), and only those that pass the requirements are invited to take part in the tender.[23] We later use a similar standard to establish a pool of qualified contractors that are eligible to participate in a particular auction.

Lastly, to control for economic trends and market dynamics during the sample period, we collect the Construction Business Survey Index (CBSI) released by the Construction and Economy Research Institute of Korea (CERIK). The CBSI is a sentiment indicator ranging between 0 and 200, where a reading above (below) 100 indicates that companies have a more optimistic (pessimistic) outlook about business conditions in the construction industry.[24]

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[22] In the United States, there is a Request for Qualifications (RFQ) stage intended to determine pre-qualifications of contractors.

[23] The PQ evaluation system has been criticized that their screening criteria are too loose and fail to exclude unqualified contractors: "it often happened that uncompetitive companies passed the prequalification assessment without difficulty and received high enough points to stand a good chance of winning the contract" (Choi and Kim, 2013). In fact, the PPS has reported that 98.6% and 98.9% of all PQ applicants had passed the evaluation in 2008 and 2009, respectively. Yet, it is also argued that the transparency of the PQ assessment allows contractors to accurately predict their own PQ score so that only those that are eligible choose to participate in the PQ process.

[24] Figure below shows the monthly CBSI between July 2007 and August 2020 for the 776 procurement auctions in the dataset (this includes auctions that are subject to the MSD rule; there are 110 cases of collusion and 666 cases of competition). The graph displays general pessimism in the industry. Note that the reading goes almost never above 100, with a negative peak in 2008 due to the financial crisis.

F1. Scatterplot of CBSI (July 2007-August 2020)

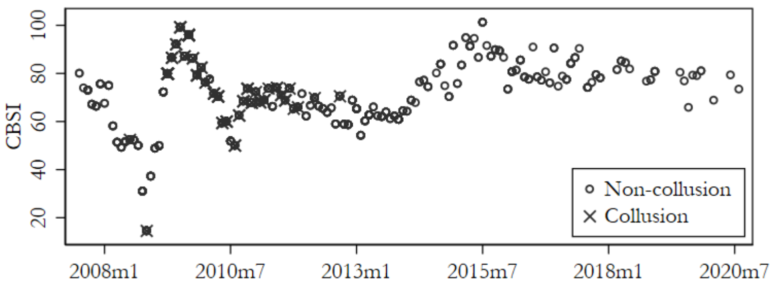


Table 3 displays the frequency distribution of project characteristics under competition and collusion. The majority of projects is delivered using DB and Weighted Criteria methods in both samples, and most collusion schemes occur in the field of civil engineering and industrial equipment between 2008 and 2012. We address the potential bias that may arise from differences in sample composition in the sensitivity analysis.

Table 3. Frequency table for categorical data

| | Non-collusion | | Collusion | |
|---|---|---|---|---|
| | Freq. | Percent | Freq. | Percent |
| Total | 492 | 100.00 | 102 | 100.00 |
| Delivery method | | | | |
| Technical Proposal | 77 | 15.65 | 1 | 0.99 |
| Alternative Bid | 42 | 8.54 | 10 | 9.90 |
| Design-Build | 373 | 75.81 | 90 | 89.11 |
| Award algorithm | | | | |
| Weighted Criteria | 453 | 92.07 | 87 | 86.14 |
| Adjusted Design Score | 35 | 7.11 | 14 | 13.86 |
| Adjusted Price | 4 | 0.81 | | |
| Type of work | | | | |
| Civil engineering | | | | |
| - Transportation | 88 | 17.89 | 32 | 31.68 |
| - Water resources | 68 | 13.82 | 35 | 34.65 |
| - Others | 22 | 4.47 | | |
| Architecture | | | | |
| - Non-residential | 183 | 37.20 | 1 | 0.99 |
| - Residential | 35 | 7.11 | 1 | 0.99 |
| Industrial equipment | 96 | 19.51 | 32 | 31.68 |
| Site location | | | | |
| Greater Seoul Metropolitan | 203 | 41.26 | 42 | 41.58 |
| Other Metropolitan | 98 | 19.92 | 20 | 19.80 |
| Local region | 191 | 38.82 | 39 | 38.61 |
| Year | | | | |
| 2007 | 22 | 4.47 | | |
| 2008 | 66 | 13.41 | 1 | 0.99 |
| 2009 | 116 | 23.58 | 60 | 59.41 |
| 2010 | 66 | 13.41 | 25 | 24.75 |
| 2011 | 59 | 11.99 | 13 | 12.87 |
| 2012 | 49 | 9.96 | 2 | 1.98 |
| 2013 | 45 | 9.15 | | |
| 2014 | 16 | 3.25 | | |
| 2015 | 18 | 3.66 | | |
| 2016 | 16 | 3.25 | | |
| 2017 | 7 | 1.42 | | |

| | | | | |
|---|---|---|---|---|
| 2018 | 6 | 1.22 | | |
| 2019 | 5 | 1.02 | | |
| 2020 | 1 | 0.20 | | |
| Winner's ranking | | | | |
| Top 10 contractor | 232 | 47.15 | 52 | 51.49 |
| Others | 260 | 52.85 | 49 | 48.51 |

*Note.* This is a frequency table for project-level information such as construction type, delivery method, award algorithm, and site location. The table excludes auctions that are subject to the MSD rule. The greater Seoul metropolitan area consists of Seoul, Incheon, and Gyeonggi Province; other metropolitan areas include Busan, Daegu, Gwangju, Daejeon, Ulsan, and Sejong. Winner is considered a top contractor if it is ranked in the top 10 in terms of execution capacity in the associated field of construction in the year the project is procured. Note that a large volume of projects is procured during the Lee administration (2008-2013). Following the global financial crisis and Great Recession, the Lee administration launched various economic stimulus plans to revive the economy, for example by expanding the social overhead capital (SOC) investments for infrastructure projects.

Bid rigging data

We infer the presence of bid rigging by the presence of antitrust enforcement by the KFTC. We assume that the KFTC's detection mechanism is effective and thorough and that their reports depict an accurate picture of why and how bidders have engaged in a collusive arrangement.[25] We examine the reports of the KFTC over the period of 2007-2020 and find 110 cases of collusion matched with the auction data. If we narrow the sample to non-MSD auctions, there are 102 cases of bid rigging detected and punished by the KFTC. As explained in Section 1.1.2, there are four types of collusion observed in the tender process: (I) price fixing, (II) design distortion, (III) cover bidding, and (IV) market division. Each of the 102 cases is classified into the four types by its nature of collusive agreement. As described in the table below, schemes (I), (III), and (IV) are detected with relatively equal

[25] It should be noted that this data may be biased by measurement error. As an antitrust investigation takes significant time and effort, the KFTC has not yet initiated proceedings on projects delivered beyond the early 2010s. There may be undetected or unpunished cases of bid rigging in projects procured after 2012. In the sensitivity analysis, we choose a narrower time window (2007-2012) and run the model again, but it does not affect the results significantly.

frequency.[26] As there is only one observation of (II), this case will not be analyzed any further.

Table 4. Winner price ratio under different types of collusion

| | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Non-collusion (2007-2020) | 492 | 90.501 | 11.995 | 41.506 | 99.998 |
| Collusion (2008-2012) | 102 | 95.401 | 3.325 | 82.527 | 99.983 |
| | | | | | |
| - Price fixing (I) | 31 | 95.398 | 3.299 | 82.527 | 99.983 |
| Price ratio 84-% fix & price handicap | 1 | 82.527 | . | 82.527 | 82.527 |
| Price ratio 92-% fix & cover bid | 1 | 91.678 | . | 91.678 | 91.678 |
| Price ratio 93+% fix | 1 | 93.171 | . | 93.171 | 93.171 |
| Price ratio 94% fix | 2 | 94.09 | .029 | 94.069 | 94.111 |
| Price ratio 95-% fix | 16 | 94.794 | .163 | 94.44 | 94.986 |
| Price ratio 95-% fix & price handicap | 2 | 94.852 | .067 | 94.805 | 94.9 |
| Price ratio 99-% fix | 3 | 98.765 | .151 | 98.6 | 98.895 |
| Price ratio 99+% fix | 4 | 99.772 | .241 | 99.5 | 99.983 |
| Price ratio 99+% fix & cover bid | 1 | 99.98 | . | 99.98 | 99.98 |
| | | | | | |
| - Design distortion (II) | 1 | 94.813 | . | 94.813 | 94.813 |
| | | | | | |
| - Cover bidding (III) | 32 | 95.7 | 3.567 | 88.465 | 99.967 |
| Unilateral cover bidding | 20 | 95.635 | 3.949 | 88.465 | 99.967 |
| Cross-cover bidding | 12 | 95.807 | 2.984 | 89.499 | 99.835 |
| | | | | | |
| - Market division (IV) | 38 | 95.166 | 3.248 | 89.6 | 99.95 |
| Unilateral cover bidding | 20 | 95.74 | 3.56 | 89.6 | 99.799 |
| Cross-cover bidding | 18 | 94.529 | 2.824 | 89.75 | 99.95 |

*Note.* The table excludes auctions that are subject to the MSD rule. The average contract price is 90.501% of the estimated price under competition but increases to 95.401% when there is collusion. We observe 2 cases of "price handicap" (see footnote 9), but this scheme is not explored in detail due to small sample size.

Table 4 shows the winner's average price ratio under competition and under different types of collusion. A price ratio is defined as the ratio of successful contract price

[26] The KFTC has detected four large cases of market division: Gyeongin canal (3 lots), Daegu Metro Line 3 (6 lots), Four major rivers (14 lots), and Incheon Metro Line 2 (15 lots).

to estimated price, multiplied by 100%.[27] On average, the contract price is 90.501% of the estimated price under competition but increases to 95.401% when there is collusion, the difference being statistically significant at the 1% level. For scheme (I), we indicate the target price ratio that bid riggers agree upon to fix price. They submit prices slightly below or slightly above this level, allowing just enough variation in prices so that it gives an impression of competitive bidding but no one has a cost advantage over another (in some cases, a conspirator receives a price handicap in order to allow firms of different sizes and capacities to compete equally; see footnote 9). One interesting observation is that the majority of cases of (I) occur at just below 95% of the estimated price. The KFTC reports suggest that this is likely due to the rumors at the time that if the price ratio exceeds 95%, the procuring entity would file complaints and request the KFTC to investigate a potential violation of competition law. Such pattern is also observed for schemes (III) and (IV). The price ratio appears to increase quite evenly from 88%, but there is an abrupt jump just before the 95% mark.[28] The fear of detection and punishment by antitrust authorities seems to be reflected in the distribution of price bids. Note that under (III) and (IV), the collusive arrangement may not be a one-time event but rather an ongoing relationship that spans over multiple projects. When bidders engage in cover bidding, the designated loser is promised to receive rewards in exchange, one form of which is to be the designated winner in another project. If conspirators engage in such bilateral or multilateral cross-cover bidding and alternate the role of a winner and a sham bidder across tenders (i.e., bid rotation), the threat of deviation may be smaller and collusion may be more likely to be sustained than when there is unilateral cover bidding. The difference between unilateral and multilateral cover bidding schemes is analyzed in more detail in the results section.

[27] In DBB projects, projected price (engineer's cost estimate) is used to determine the successful bidder and contract amount prior to the tender or the conclusion of contract. Yet, in DB projects, projected price is not provided given that the owner does not have the design documents prior to the tender. We hence use the estimated price, which is the pre-design cost estimate prepared by the procuring entity before determining the projected cost, as a benchmark for evaluating price bids. The preliminary cost estimate essentially serves as an upper bound on bids.

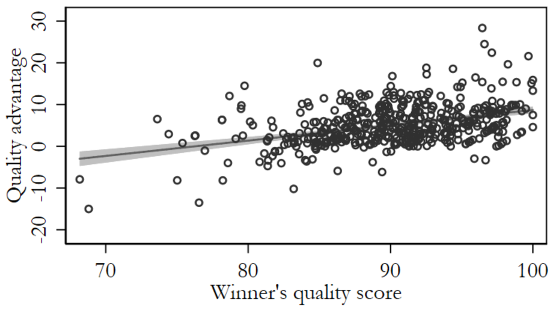
[28] There is a jump from 94.95% to 97.85% under (III) and from 94.98% to 96.12% under (IV).

### *1.3.1 Bidding behavior under competition and collusion*

In a price-only auction, the bidder that offers the lowest price is awarded the contract. In the case of multi-criteria auctions, the bidder that achieves the highest overall score is selected as the winner. Note that this bidder may not be the cheapest bidder nor the best designer. Six different winning scenarios can be observed: highest-quality/highest-price (HQ/HP), highest-quality/middle-price (HQ/MP), highest-quality/lowest-price (HQ/LP), middle-quality/middle-price (MQ/MP), middle-quality/lowest-price (MQ/LP), and lowest-quality/lowest-price (LQ/LP). Table 5 displays the frequency distribution of these scenarios under competition and collusion and, for each case, the winner's average price ratio and quality advantage. We define quality advantage as the difference between the winner's quality score and the average quality score of losers, divided by the average quality score of losers.[29] We choose not to report raw quality scores in Table 5 because design assessment is subjective and depends on the method of evaluation. A bidder that receives a quality score of 100 in one auction does not mean that its design is superior to a design proposal of a lower score in another auction. As the quality advantage variable normalizes the winner's quality score by the auction average, it is more informative about the winner's technical superiority and allows comparison across auctions.[30]

[29] A quality advantage is defined by $\left(q^W - \overline{q^{/W}}\right)/\overline{q^{/W}}$, where $q^W$ is the winner's quality score and $\overline{q^{/W}}$ is the average quality score of auction participants excluding the winner. The scatterplot below shows a positive relationship between the winner's quality score and quality advantage.

F2. Scatterplot of winner's quality score and quality advantage




[30] To analyze the quality advantage variable, it is critical that we restrict the sample to non-MSD auctions; otherwise, the quality score differences would be distorted by the definition and intensity of the rule.

Note that in the absence of bid rigging (Panel A), the winner is the best designer in 9 out of 10 cases and is the lowest-price bidder in almost half of all cases. This finding is somewhat surprising because in previous studies, the winner is frequently not the best designer in DB auctions. Takahashi (2018) reports that the winner received a non-highest quality score in 48.1% of cases in Japan, and Albano et al. (2008) reports that the winner did not obtain the highest technical score in 4 out of 20 cases in Italy. A working paper published by the World Bank notes that the winner did not earn the highest technical score in 36% of cases (Casartelli and Wolfstetter, 2007). The fact that the winner is the HQ/LP bidder in 38% of cases and the best designer in 90% of cases may imply that procuring entities in Korea are quite successful in ensuring cost efficiency and high-quality design for public construction projects.[31]

Another point to note is that price and quality move together in general. We observe that in Panel A (a), the price ratio of winners that propose the best design is significantly higher than that of lower-quality winners, and in Panel A (b), the quality advantage of winners that offer the most expensive bid is significantly higher than that of cheaper-bidding winners.[32] As high-quality design tends to generate high costs, it is likely to be associated with high price. Likewise, for a bidder to be awarded a contract with a low-quality design, it must submit a considerably low price and achieve a high price score that could counterbalance its disadvantage in the quality dimension. Note that there are 25 cases in which the winner submits the lowest-quality/lowest-price (LQ/LP) bid. This indicates the presence of aggressive, even predatory, price bidding.[33] Without these

[31] Under Weighted Criteria, bidders may behave aggressively in both dimension (and potentially compromise on its profit margin) as there is high uncertainty about the behavior of other bidders. As previously noted, the score interdependency makes it difficult for a bidder to determine its optimal bid and score. Bidders may be unsure about their chances of winning and thus behave aggressively regardless of their strength and capabilities.

[32] It appears that the quality advantage in HQ/MP is greater than that of HQ/HP, but this likely due to the difference in number of bidders. If we limit the sample to auctions that have more than two bidders, the average quality of advantage of the HQ/HP case increases to 7.414 (39 observations).

[33] Although not reported, the difference between the maximum and minimum price bids is greater than 10% of the estimated price in 69 cases (approximately 14%), which is a fairly large proportion. This suggests that there is some threat of aggressive bidding that represses bidders from raising prices. A bid proposal of lower quality is ranked first by the scoring rule in 47 and 2 cases in the competitive and collusive samples, respectively. Detailed discussion of these cases is in Appendix 1.A.4.

observations, the average price ratio under competition increases to 91.59%. Even so, the price ratios are generally higher when there is collusion among bidders (Panel B).

Table 5. Winning scenarios under competition and collusion

Panel A. Under competition

(a) Winner price ratio (Frequency)

| Quality \ Price | Highest | Middle | Lowest | Total |
|---|---|---|---|---|
| Highest | 95.59 (189) | 92.47 (68) | 90.71 (185) | 93.07 (442) |
| Middle | | 71.07 (5) | 63.90 (20) | 65.34 (25) |
| Lowest | | | 70.24 (25) | 70.24 (25) |
| Total | 95.59 (189) | 91.0 (73) | 86.16 (230) | 90.50 (492) |

(b) Winner quality advantage (Relative frequency)

| Quality \ Price | Highest | Middle | Lowest | Total |
|---|---|---|---|---|
| Highest | 7.79 (38.4%) | 8.72 (13.8%) | 6.39 (37.6%) | 7.35 (89.8%) |
| Middle | | 0.62 (1.0%) | 1.58 (4.1%) | 1.39 (5.1%) |
| Lowest | | | -5.89 (5.1%) | -5.89 (5.1%) |
| Total | 7.79 (38.4%) | 8.17 (14.8%) | 4.64 (46.8%) | 6.37 (100%) |

Panel B. Under collusion

(a) Winner price ratio (Frequency)

| Quality \ Price | Highest | Middle | Lowest | Total |
|---|---|---|---|---|
| Highest | 96.03 (45) | 93.07 (11) | 95.44 (44) | 95.44 (100) |
| Middle | | 94.79 (1) | 92.0 (1) | 93.39 (2) |
| Total | 96.03 (45) | 93.21 (12) | 95.36 (44) | 95.40 (102) |

(b) Winner quality advantage (Relative frequency)

| Quality \ Price | Highest | Middle | Lowest | Total |
|---|---|---|---|---|
| Highest | 8.81 (44.1%) | 14.23 (10.8%) | 9.94 (43.1%) | 9.90 (98.0%) |
| Middle | | 0.34 (1.0%) | 3.08 (1.0%) | 1.71 (2.0%) |
| Total | 8.81 (44.1%) | 13.07 (11.8%) | 9.79 (44.1%) | 9.74 (100%) |

*Note.* The table shows the winner's (a) price ratio and (b) quality advantage under competition in Panel A and under collusion in Panel B. The column headers indicate whether the winner's price bid is the highest (tie), lowest, or middle value. The row headers indicate whether the winner's quality bid is the highest (tie), lowest, or middle value. Six different winning scenarios are observed: highest-quality/highest-price (HQ/HP), highest-quality/middle-price (HQ/MP), highest-quality/lowest-price (HQ/LP), middle-quality/middle-price (MQ/MP), middle-quality/lowest-price (MQ/LP), and lowest-quality/lowest-price (LQ/LP). In Panel A, there are three cases of tied quality score assigned to HQ/LP and one case of tied price assigned to HQ/HP. Numbers in brackets in (a) and (b) represent frequency and relative frequency of the winning scenarios, respectively.

Panel B displays a similar pattern of winning scenarios as Panel A. The winner is the best designer in all but two cases (see Appendix 1.B) and is the lowest-price bidder in 44% of cases. However, we must not forget that many of these bids are fabricated such that they give an impression of competition. When a firm receives a tender notice, it has to make several decisions: whether or not to enter the auction; and, having done so, how to choose its quality and price bids. We believe that all three types of bid rigging can distort both of these decisions. When bidders fix both price and quality ((III) cover bidding and (IV) market division), competition is entirely eliminated as they arrange in advance who would enter and what to bid. The number of bidders is endogenously determined regardless of market conditions and bidder interests, and their bid proposals do not reflect the differences in their financial and technical ability. As for a one-sided fixing scheme ((I) price fixing), one might argue that it creates less distortion in bidders' decision-making because there remains some competition and the plot is typically set up after the PQ evaluation or the on-site explanation of a project (see Appendix 1.A for the tender process). Yet, we must note that not all potential bidders are actual bidders under competitive tendering. They decide whether or not to participate in the bidding process after conducting a cost-benefit analysis. When there is no collusion, the number of firms that apply for PQ evaluation does not match with the actual number of bidders in 90 out of 258 cases; when there is scheme (I), the numbers do not match in 10 out of 22 cases.[34] This suggests that scheme (I) can affect who decides to leave or stay for a tender. For instance, a bidder that has a low chance of winning may be discouraged to bid when the playing field does not seem level if the price were to be fixed. Even if it does participate, it may have no intention of winning; it may not try as hard and submit a bid only to give an image of competition because scheme (I) can involve the winner paying rewards to losers (for example, offering a consolation prize; see footnote 9 for more information).

[34] We must warn that we only know the number and identity of PQ applicants and do not know whether or not they have passed the evaluation. Yet, multiple sources report that almost all PQ applicants pass the evaluation (see footnote 23). This may be because construction firms are well aware of their technical and financial standing and choose to participate in PQ only when they can meet the qualification requirements.

Table 6. Statistics of key variables

| Type | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| (a) Number of bidders | | | | | |
| Non-collusion | 492 | 2.577 | .866 | 2 | 8 |
| Collusion | 102 | 2.465 | .819 | 2 | 6 |
| - (I) price fixing | 31 | 3.129 | 1.024 | 2 | 6 |
| - (III) cover bidding | 32 | 2.031 | .177 | 2 | 3 |
| - (IV) market division | 38 | 2.289 | .611 | 2 | 5 |
| (b) Winner quality advantage | | | | | |
| Non-collusion | 492 | 6.372 | 6.474 | -17.9 | 41.63 |
| Collusion | 102 | 9.716 | 4.942 | .342 | 23.292 |
| - (I) price fixing | 31 | 8.065 | 5.165 | .342 | 18.128 |
| - (III) cover bidding | 32 | 11.536 | 4.76 | 4.29 | 23.292 |
| - (IV) market division | 38 | 9.747 | 4.422 | 2.761 | 20.573 |
| (c) Difference in execution capacity between winner and losers | | | | | |
| Non-collusion | 490 | .283 | 1.043 | -3.463 | 4.419 |
| Collusion | 100 | .474 | 1.249 | -2.309 | 3.719 |
| - (I) price fixing | 31 | -.019 | .959 | -1.677 | 2.176 |
| - (III) cover bidding | 32 | .593 | 1.399 | -1.651 | 3.719 |
| - (IV) market division | 37 | .792 | 1.226 | -2.309 | 3.194 |

*Note*. See footnote 29 for the definition of winner's quality advantage. See footnote 35 for the definition of winner's execution capacity relative to losers.

Table 6 provides descriptive statistics for (a) the number of bidders, (b) the winner's quality advantage, and (c) the difference in execution capacity between winner and losers under competition and different types of collusion.[35] Under competition, the average number of bidders is 2.577 and the average quality advantage is 6.372. When there is bid rigging, the two variables show different behavior depending on the form of collusive arrangement. The tests for differences in means indicate that, first, number of bidders is statistically greater under (I) and smaller under (III) and (IV) than under competition. This

[35] The execution capacity of the winner compared to other bidders is defined by $\ln(EC^W) - \overline{\ln(EC^{/W})}$, where $\ln(EC^W)$ is the log execution capacity of the winner and $\overline{\ln(EC^{/W})}$ is the average of the log execution capacity of the losers. A value greater (less) than 0 implies the winner's execution capacity is larger (smaller) than the auction average. We expect that a bidder with high execution capacity has a higher technical capability than a bidder with low execution capacity.

is consistent with our expectations and supports the need to control for the effect of bid rigging on a bidder's participation decision. Second, the winner's quality advantage is statistically greater under all three types of collusion than under competition. It is important to point out that under (I), both quality advantage and relative execution capacity are as widely spread out as under the other schemes, ranging from 0.342 to 18.128 and from -1.677 to 2.176, respectively. This suggests that not all conspirators of scheme (I) are equally technically competent and that not all of them bid aggressively for high quality with an intention to win. This supports the need to remove the bias created in the quality dimension for all three types of collusion.

### *1.3.2 Building a pool of qualified contractors*

The primary goal of the present study is to estimate the auction outcome in the absence of a collusion scheme when all bidders behave genuinely and competitively. Yet, we do not have information on various factors that may influence their price and quality decision, such as the identity of competitors, their cost distribution and risk attitudes, and the amount of information that they have about the auction. To counteract this problem, we imagine an average contractor that would have entered the auction if there were no bid rigging. In order to do so, we create a pool of contractors that are capable of undertaking each project, using a standard similar to what is used by a procuring entity during the actual prequalification process. Two factors are evaluated: a contractor's (1) experience and performance on projects of similar nature and complexity and its (2) execution capacity in the construction field of the given project. For the first part, we consider not only the 821 observations in our main sample (including MSD auctions) but also the 3,002 observations of public projects with budget over 10 billion KRW procured between 1997-2020. These projects are manually classified into six categories and further subdivided into 11 subcategories of construction work described in Table 7. We determine the number of projects a firm has completed successfully as a sole contractor or as a consortium leader for each of the 11 construction types. We also calculate its total performance record over the five years preceding the current year for each of the six categories (see footnote 21).[36]

Table 7. Types of construction work

| Field | Category | Subcategory |
|---|---|---|
| (i) Civil engineering | (1) transport infrastructure | (1.1) railway and subway<br>(1.2) other transportation |
| | (2) waterworks | (2.3) harbor<br>(2.4) riverworks and agricultural engineering<br>(2.5) other waterworks |
| | (3) other civil engineering | (3.6) other civil engineering |
| (ii) Architecture | (4) non-residential | (4.7) exhibition, assembly, and sports facility<br>(4.8) other non-residential |
| | (5) residential | (5.9) residential |
| (iii) Industrial equipment | (6) industrial equipment | (6.10) wastewater<br>(6.11) other industrial equipment |

As for the second part, we consider the execution capacity of construction firms in each of the three fields: (i) civil engineering, (ii) architecture, and (iii) industrial equipment.[37] In real-word cases of procurement, the procuring entity often limits PQ application or tender participation based on the execution capacity of contractors. The PPS has a registry of construction firms assigned into seven grades based on execution capacity, with Grade 1 being the highest and Grade 7 being the lowest category. Each grade level is associated with a range of project value a contractor can undertake in the field of (i) and (ii), while no such standard is available for (iii). The purpose of the registry is to exclude contractors that are incapable of delivering a project and to promote participation of small and medium-sized contractors in small projects. A contracting authority can use the registry in one of two ways: limit participation to contractors only in the associated grade level or allow entry of contractors of superior grades. As the first approach can be too

[36] The actual PQ evaluation considers performance record within the last five years (or 10 years) before the date of tender notice. We use the alternative definition because only annual data are available.

[37] In practice, the grading system of the PPS and the PQ evaluation of contractors use the comprehensive measure of execution capacity in civil engineering and building works, rather than separate measures of (i) civil engineering and (ii) civil building (see footnote 20). We use the alternative specification to better capture the bidding capacity of a contractor in each field of construction.

restrictive, we take the latter approach. We construct a grading standard similar to that of the PPS in Panel A of Table 8. We group (iii) together with (ii) because they are relatively small in size compared to (i). According to this standard, about 34 contractors falls in Grade 1 (not shown), and about a third of projects in the sample are associated with Grade 1 (Panel B).

Table 8. Restrictions on execution capacity

Panel A. Grading of contractors

| Grade | Execution capacity (i),(ii),(iii) (1 billion KRW) | Estimated price (1 billion KRW) | |
|---|---|---|---|
| | | (i) | (ii), (iii) |
| 1 | 500 < | 150 < | 110 < |
| 2 | 500 ~ 100 | 150 ~ 85 | 110 ~ 85 |
| 3 | 100 ~ 50 | 85 ~ 50 | 85 ~ 50 |
| 4 | 50 ~ 30 | 50 ~ 36 | 50 ~ 36 |
| 5 | 30 ~ 18 | 36 ~ 20 | 36 ~ 20 |
| 6 | 18 ~ 12 | 20 ~ 13 | 20 ~ 12 |
| 7 | 12 > | 13 > | 12 > |

*Note.* This is based on the grading system of the PPS in 2014. (i), (ii), and (iii) denotes architecture, civil engineering, and industrial equipment, respectively. Suppose there is a civil engineering project with an estimated price of 60 billion KRW. Since Grade 3 is associated with a project value between 50-85 billion KRW, contractors of Grade 3 and higher in (ii) can undertake the project.

Panel B. Sample

| Grade | Number of projects | |
|---|---|---|
| | N | % |
| 1 | 267 | 33.71 |
| 2 | 151 | 19.07 |
| 3 | 147 | 18.56 |
| 4 | 87 | 10.98 |
| 5 | 85 | 10.73 |
| 6 | 45 | 5.68 |
| 7 | 10 | 1.26 |

*Note.* This shows the number of projects that corresponds to each grade level. This includes auctions that are subject to collusion or the MSD rule.

We have collected information on 90 contractors that may be eligible to participate in a multi-attribute procurement auction.[38] We argue that a contractor that satisfies the following conditions is qualified to undertake a project:

(q.i) It has completed at least one project successfully (as a sole contractor or as a consortium leader) in the same construction subcategory as a given project.

[38] There are 63 distinct winners and 102 distinct bidders in the 492 observations of non-collusion and non-discrimination.

(q.ii) Its total performance record over the last five years (preceding the current year) in the same construction category as a given project is greater than the estimated price of a given project.

(q.iii) Its grade level is associated with a range of values equal or greater than the estimated price of a given project.

Yet, we must note that even if a contractor is eligible to participate in a project, it can have no intention of doing so. In general, large construction firms are less interested in small-scale projects, which are likely to have slim profit margins, while small firms are less inclined to participate in large-scale projects, for they have a low chance of winning. Let us say a construction firm is a *top contractor* if it is a Top 10 firm in terms of execution capacity in each of the three fields. The average size of projects that top contractors have participated in tendering is 147.2 billion KRW (281 out of 492 observations), whereas the average value of projects that top contractors showed no interest is 60.9 billion KRW. About 85% of Grade 1 projects have at least one bidder that is a top contractor, while only 44% of lower-grade projects have a bidder that is a top contractor. These observations suggest that an additional condition of participation restriction is necessary to take into account the bidding environment where small and large firms compete in different auctions. In Table 9, we compare the ratio of top contractors to actual bidders and the ratio of top contractors to qualified contractors (i.e., those that satisfy conditions (q.i), (q.ii), and (q.iii)). When the winner is not a top contractor, none of the auction participants is a top contractor for 80.99% of the cases; this quantile corresponds to 0.364 for the proportion of top contractors in the qualified contractor pool. Meanwhile, when the winner is a top contractor, the proportion of bidders that are top contractors reaches 1 at the 0.42.98-quantile; this corresponds to 0.321 for the proportion of top contractors in the qualified contractor pool. On these grounds, we introduce the fourth condition that decides whether an auction consists of bidders that are only top contractors, only non-top contractors, or both:

(q.iv) It is a top contractor when (a) the winner is a top contractor and (b) the proportion of top contractors in a qualified contractor pool exceeds the threshold value 0.321. It is a non-top contractor when (a) the winner is not a top contractor and (b) the ratio of top contractors in qualified contractor pool is less than the threshold value 0.364. Otherwise, both types of contractors are allowed in the pool.

To put it simply, we assume that the more top contractors are qualified to undertake a project, the less likely non-top contractors participate in the auction. When the winner is not a top contractor, auction participants would be made up of all non-top contractors for 81% of the cases, where auctions are sorted in ascending order by the proportion of top contractors in the pool. On the other hand, when the winner is a top contractor, bidders would be made up of all top contactors for 57% of the cases, where auctions are sorted in descending order by the proportion of top contractors in the pool.

Table 9. Ratio of top contractors in competitive auctions

| | | N | Min | p5 | p25 | p50 | p75 | p90 | Max |
|---|---|---|---|---|---|---|---|---|---|
| Non-Top 10 winner | $\frac{\text{Number of Top 10 bidders}}{\text{Number of bidders}}$ | 260 | 0 | 0 | 0 | 0 | 0 | .333 | .667 |
| | $\frac{\text{Number of Top 10 qualified}}{\text{Number of qualified}}$ | 260 | .155 | .175 | .224 | .286 | .333 | .419 | .6 |
| Top 10 winner | $\frac{\text{Number of Top 10 bidders}}{\text{Number of bidders}}$ | 232 | .25 | .333 | .5 | 1 | 1 | 1 | 1 |
| | $\frac{\text{Number of Top 10 qualified}}{\text{Number of qualified}}$ | 232 | .169 | .213 | .294 | .323 | .405 | .474 | .8 |

*Note*. This shows the proportion of top contractors out of qualified contractors and the proportion of top contractors out of actual bidders in the 492 auctions that are not subject to collusion nor the MSD rule.

Panel A of Table 10 reports what proportion of bidders actually meet each of the four qualification requirements in the 492 auctions that are not subject to collusion nor the MSD rule. Overall, 92% of the winners and 75% of the losers are successfully classified into the pool. Note that conditions (q.i), (q.ii), and (q.iii) are satisfied with over 90% probability, while condition (q.iv) has a fairly low probability. This indicates that there is some discrepancy between the ratio of top contractors to qualified contractors and the ratio of top contractors to actual bidders. Yet, we do not find this to impose a serious problem in our analysis because when we run the models again using only auctions with bidders that satisfy all four requirements (354 observations) in the sensitivity analysis, the findings remain valid (see Appendix 1.C and Appendix 1.D).

Panel B of Table 10 displays the average number of bidders and the average number of qualified contractors broken down by construction category. The number of qualified contractors should depend on the size and complexity of projects and the occurrence of similar types of work. Note that the size of the pool is smaller on average under collusion than under competition. This could imply that firms have a higher incentive to collude when there are fewer potential bidders, but further research is necessary to confirm this claim.

Table 10. Statistics of qualified contractor pool

Panel A. Bidder qualifications (%)

| Variable | Obs | Qualified | (q.i) | (q.ii) | (q.iii) | (q.iv) |
|---|---|---|---|---|---|---|
| Winner | 492 | 91.667 | 93.699 | 96.748 | 99.39 | 100 |
| Loser 1 | 492 | 76.22 | 90.244 | 94.512 | 99.39 | 88.008 |
| Loser 2 | 195 | 75.897 | 93.333 | 94.872 | 98.974 | 86.154 |

*Note.* The sample of observations that we use to measure past experience of contractors for condition (q.i) may be incomplete since we only have information on public contracts, which are issued by government agencies, local governments, public organizations, and public enterprises. We do not have information on private projects commissioned by private sector entities and foreign agencies.

Panel B. Number of qualified contractors by construction category

| | | Number of bidders | Number of qualified contractors | | |
|---|---|---|---|---|---|
| Competition | N | Mean | Mean | Min | Max |
| (1) transport infrastructure | 88 | 2.864 | 30.295 | 9 | 49 |
| (2) waterworks | 68 | 2.706 | 16.338 | 5 | 38 |
| (3) other civil engineering | 22 | 2.364 | 21.636 | 6 | 39 |
| (4) non-residential | 183 | 2.448 | 30.148 | 7 | 59 |
| (5) residential | 35 | 2.6 | 13.114 | 6 | 26 |
| (6) industrial equipment | 96 | 2.51 | 16.063 | 6 | 30 |
| Collusion | N | Mean | Mean | Min | Max |
| (1) transport infrastructure | 32 | 2.25 | 22.938 | 9 | 45 |
| (2) waterworks | 35 | 2.686 | 11.371 | 5 | 25 |
| (3) other civil engineering | | | | | |
| (4) non-residential | 1 | 3 | 42 | 42 | 42 |
| (5) residential | 1 | 2 | 6 | 6 | 6 |
| (6) industrial equipment | 32 | 2.424 | 15.848 | 7 | 23 |

*Note*. In the absence of bid rigging and the MSD rule, the average number of qualified contractors is 22. When collusion is present, the average size of the qualified contractor pool is 17.

We now introduce two variables that make use of the qualified contractor pool. First, we calculate the average backlog ratio of qualified contractors for each auction, $\overline{BLG^{QC}}$, as a proxy for their capacity utilization rate. We expect that when contractors have heavy workload on average, a fewer number of them would be interested in undertaking a new project. We thus use this variable in the estimation of the number of bidders expected to participate in a particular auction. Second, we normalize the winner's technical ability by that of qualified contractors. The winner's relative execution capacity is defined by $REC^{QC} = \ln(EC^{W}) - \overline{\ln(EC^{QC/W})}$, where $\ln(EC^{W})$ is the log execution capacity of the winner and $\overline{\ln(EC^{QC/W})}$ is the average of the log execution capacity of qualified contractors excluding the winner. A value greater (less) than 0 implies that the winner is generally superior (inferior) to other contractors in terms of technical ability. This variable is used in the estimation of the winner's quality advantage in a particular auction.

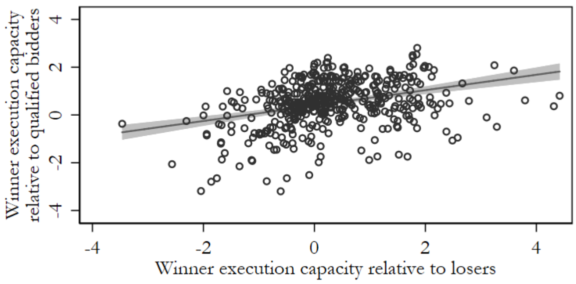
Table 11. Statistics of variables related to qualified contractor pool

| Variable | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| $\overline{BLG^{B}}$ | 491 | .617 | .151 | .021 | .969 |
| $\overline{BLG^{QC}}$ | 492 | .615 | .087 | .362 | .826 |
| $REC^{B}$ | 490 | .283 | 1.043 | -3.463 | 4.419 |
| - *Non-Top winner* | 258 | -.009 | 1.042 | -3.463 | 4.316 |
| - *Top winner* | 232 | .609 | .945 | -1.107 | 4.419 |
| $REC^{QC}$ | 492 | .472 | .981 | -3.196 | 2.809 |
| - *Non-Top winner* | 260 | .101 | 1.007 | -3.196 | 1.95 |
| - *Top winner* | 232 | .888 | .762 | -.949 | 2.809 |

*Note*. $\overline{BLG^{B}}$ denotes the average backlog ratio of actual bidders, and $\overline{BLG^{QC}}$ denotes the average backlog ratio of qualified contractors. $REC^{B}$ denotes the difference in execution capacity between winner and losers, and $REC^{QC}$ denotes the difference in execution capacity between winner and qualified contractors (excluding the winner).

Table 11 compares the two variables, $\overline{BLG^{QC}}$ and $REC^{QC}$, with the average backlog ratio of actual bidders ($\overline{BLG^{B}}$) and the relative execution capacity between winner and losers ($REC^{B}$), respectively. In the case of backlog ratio, $\overline{BLG^{B}}$ and $\overline{BLG^{QC}}$ show similar behavior, with Pearson's correlation of 0.44. In the case of relative execution capacity, $REC^{QC}$ appears greater than $REC^{B}$ on average, with Pearson's correlation of 0.39. As the size of the qualified contractor pool is substantially larger than the number of actual bidders (see Panel B of Table 10), many of the qualified contractors that did not participate in the auction are likely to be of lower ability compared to actual bidders, thereby pulling $\overline{\ln(EC^{QC/W})}$ downward. Figure 1 below illustrates the relationship between the two relative execution capacity variables. The flat slope of the fitted line suggests that $REC^{QC}$ may underestimate (overestimate) winner's technical superiority when it has a very high (low) execution capacity compared to other bidders. Despite such limitations, we use the qualified contractor pool as the basis for comparison for these variables assuming that this approach provides a reasonable explanation of how bidders behave in the absence of collusion.

Figure 1. Scatterplot of relative execution capacity variables




*Note*. The horizonal axis is the difference in execution capacity between winner and losers ($REC^{B}$), and the vertical axis is the difference in execution capacity between winner and qualified contractors ($REC^{QC}$). The fitted line is flatter than the 45-degree line.

### *1.3.3 Descriptive statistics*

See Table 12 for descriptive statistics. The estimated price of a project reflects the size and scale of work. In our sample, a project is launched with a budget about 110 billion KRW on average. Number of bidders in an auction implies the overall level of competition, and the weight on evaluation factors (under Weighted Criteria) infers the owner's degree of emphasis on the technical and financial aspect of a proposal. The weight on quality is typically greater than that of price, implying the importance of design and quality control in government-funded projects. The table also reports whether the winner's headquarters is located in the same province as the project.[39] Studies have shown that local and incumbent firms are often more experienced and informed about the project and thus more likely to be successful than non-local and entrant firms. In our main analysis, we do not consider this variable because most bidders (consortium leaders) are based in the Seoul metropolitan area; it is likely that these firms form a bidding consortium with a regional construction company to pool information, resources, and finances when competing for a project in a local region. Note that bidders engage in joint bidding in 96% of cases, with a consortium leader holding about 47% stake on average. Firms can be less concerned about their capacity constraints (i.e., high backlog of orders) or potential disadvantage arising from geographical distance because they can work together in a consortium or subcontract parts of work to another firm.

Table 12. Descriptive statistics

| Variable | Type | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|---|
| - *Auction characteristics:* | | | | | | |
| Estimated price (1 billion KRW) | Non-collusion | 492 | 110.064 | 87.667 | 5.264 | 595 |
| | Collusion | 102 | 116.912 | 100.482 | 4.695 | 384.715 |
| Number of bidders | Non-collusion | 492 | 2.577 | .866 | 2 | 8 |
| | Collusion | 102 | 2.461 | .817 | 2 | 6 |
| Alternative bidders (under Alternative Bid) | Non-collusion | 27 | 2.778 | .934 | 1 | 5 |
| | Collusion | 7 | 1.857 | .69 | 1 | 3 |
| Original bidders (under Alternative Bid) | Non-collusion | 6 | 4 | 3.464 | 1 | 9 |
| | Collusion | 3 | 1.333 | .577 | 1 | 2 |

[39] Some studies use bidder's distance to the contract site, but such information is unavailable.

| | | | | | | |
|---|---|---|---|---|---|---|
| Weight on quality (%) (under Weighted Criteria) | Non-collusion | 453 | 60.318 | 9.294 | 30 | 80 |
| | Collusion | 87 | 62.529 | 7.427 | 45 | 80 |
| - *Winner characteristics:* | | | | | | |
| Winner backlog ratio | Non-collusion | 490 | .605 | .21 | .003 | 1 |
| | Collusion | 102 | .628 | .206 | .317 | 1 |
| Headquartered in project location | Non-collusion | 492 | .348 | .477 | 0 | 1 |
| | Collusion | 102 | .373 | .486 | 0 | 1 |
| Winner price ratio (%) | Non-collusion | 492 | 90.501 | 11.995 | 41.506 | 99.998 |
| | Collusion | 102 | 95.401 | 3.325 | 82.527 | 99.983 |
| Winner quality score | Non-collusion | 492 | 90.123 | 5.384 | 68.17 | 100 |
| | Collusion | 102 | 90.182 | 3.501 | 79.4 | 99 |
| Winner quality advantage | Non-collusion | 492 | 6.372 | 6.474 | -17.9 | 41.63 |
| | Collusion | 102 | 9.741 | 4.924 | .342 | 23.292 |
| Bidding consortium | Non-collusion | 467 | .959 | .198 | 0 | 1 |
| | Collusion | 102 | 1 | 0 | 1 | 1 |
| Number of consortium members | Non-collusion | 448 | 4.368 | 1.59 | 1 | 10 |
| | Collusion | 102 | 5.353 | 1.86 | 2 | 10 |
| Leader's stake (%) | Non-collusion | 448 | 47.489 | 10.567 | 28 | 90 |
| | Collusion | 102 | 43.77 | 9.039 | 29 | 75 |

*Note.* Winner backlog ratio is the ratio of the winner's current backlog over its maximum amount during the sample period. Winner price ratio is the ratio of successful contract price to estimated price in percentage terms. Winner quality advantage is the winner's quality score minus the average quality score of losers, divided by the average quality score of losers. Leader's stake indicates the share of bid value held by the consortium leader.

## 1.4 The Model

We employ a reduced-form forecasting method to predict the counterfactual scenario of bid rigging in a multi-criteria procurement auction. Our methodology consists of two stages. First, using observations of non-collusive auctions, we estimate regressions of number of bidders $N$ and winner's quality advantage $T$. The resulting coefficient estimates are used to predict the expected number of bidders $\widehat{N}$ and the expected quality advantage $\widehat{T}$ for observations of collusive tendering. Second, we use these estimates as instrumental variables for $N$ and $T$ in the regression of contract price $P$. The predicted value is the counterfactual competitive price of collusion, $\widetilde{P}$.

<u>Baseline model specification:</u>

In the second stage, we estimate the following regression equation:

$$P_i = \beta_0 + \beta_1 N_i + \beta_2 T_i + \beta_3 \boldsymbol{Z_i^P} + \epsilon_{it}, \tag{1.a}$$

where the dependent variable $P_i$ is the logarithm of contract price for auction $i$. The unobserved attributes are captured by the residual term. The set of regressors $\boldsymbol{Z_i^P}$ includes the following:

- winner-specific: winner backlog ratio of current quarter
- auction-specific: logarithm of estimated price, quality weight[40], delivery method dummy, auction algorithm dummy, region dummy, government dummy, construction subcategory dummy
- market-level: CBSI (monthly)

In the presence of collusion, we do not expect $N$ and $T$ to affect the winning bid as they would under a competitive setting. Hence, we estimate the expected outcomes, $\widehat{N}$ and $\widehat{T}$, in a hypothetical scenario where there is no bid rigging. In the first stage, the models are of the form:

$$N_i = \beta_0 + \beta_1 \boldsymbol{Z_i^N} + \epsilon_{it}, \tag{1.b}$$

$$T_i = \beta_0 + \beta_1 N_i + \beta_2 \boldsymbol{Z_i^T} + \epsilon_{it}. \tag{1.c}$$

In Equation $(1.b)$, $\boldsymbol{Z_i^N}$ contains auction- and market-related predictors as follows:

- auction-specific: logarithm of estimated price, quality weight, average backlog ratio of qualified contractors, delivery method dummy, auction algorithm dummy, region dummy, government dummy, construction subcategory dummy
- market-level: CBSI

We do not consider bidder-related variables in this model because at the time of entry, contractors do not know exactly who they will be competing against in the auction. They make the entry decision on the basis of tender characteristics and market conditions, accepting the costs and risks associated with participation (and withdrawal).

---

[40] For auctions that do not adopt the Weighted Criteria algorithm, we assign 0.5 to both weights.

In equation $(1.c)$, the following variables are considered in $\boldsymbol{Z}_i^T$:

- winner-specific: winner's relative execution capacity ($REC^{QC}$)[41], past projects completed successfully in the same construction subcategory[42]
- auction-specific: logarithm of estimated price, quality weight, delivery method dummy, auction algorithm dummy, region dummy, government dummy, construction subcategory dummy

We expect winner's relative execution capacity and its performance records in similar projects to be important determinants of its quality advantage.

## 1.5 Results and Discussion

### *1.5.1 Price estimation*

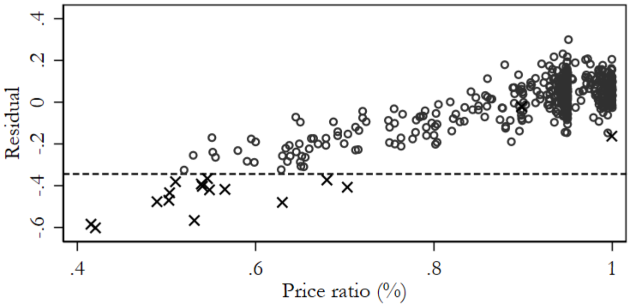
The regression results are presented in Table 13 (p-values in parentheses). Note that all of the regressions are estimated after removing outliers. Cases where the regression residual is not within three standard deviations from the mean are considered an outlier. We found 17 outliers out of 492 observations.[43]

[41] Winner's relative capacity is measured by $\ln(\text{execution capacity of winner}) - \ln(\text{execution capacity of qualified contractors excluding winner})$.

[42] Winner's performance record is measured by $\ln(\text{Number of winner's past experience} + 1)$.

[43] The figure below shows the scatterplot of regression residuals against the winner's price ratio. Observations with a residual less than -0.344 (orange line) are considered outliers.

F3. Scatterplot of observations and outliers



The first column contains estimates of Equation $(1.b)$ with number of bidders as the dependent variable. Bidder participation is positively correlated with the size of projects and is negative related to the quality weight, although not statistically significant.[44] The average backlog ratio of qualified contractors is also negative but not statistically significant; this may be because contractors often participate as a consortium so the pending workload does not significantly affect their participation decision. For delivery type, the number of bidders is greater under AB and lower under TP compared to DB auctions. This is likely due to the fact that the rule of bid compensation was not adopted for TP until 2015; the high bid preparation cost can act as a barrier to entry, especially for small and weak contractors.[45] In contrast, the entry cost for AB auctions can be comparatively low because bidders can participate with the original proposal provided by the owner (in such case, they only submit price bids). We also find some regional differences (not reported); the number of bidders is greater in local regions than metropolitan areas, as local and regional construction companies are more likely to participate in these projects.

Column (2) of Table 13 gives estimates of Equation $(1.c)$, using quality advantage of the winner as the dependent variable. The quality score difference is strongly negatively related to the estimated price, suggesting that design competition becomes more aggressive with project size. It is positively correlated with bidder participation because the average quality score of losers decreases with the number of bidders.[46] The estimated coefficient of winner's past experience is also positive, significant at the 10% level. Another key

[44] We presume that an owner is more likely to choose a large quality weight when the project is technically complex and sensitive, and firms become less interested in bidding if the owner sets a high bar for applicants.

[45] Bid compensation is a stipend or honorarium paid by the procurement authority to the unsuccessful bidders to compensate them for the preparation of their proposal. The formula used for the calculation of bid compensation has been modified several times. Under AB, the honorarium is defined as a fixed percentage of the estimated price depending on the number of bidders, and under DB, it is calculated based on a bidder's quality score relative to other recipients. The honorarium for TP projects is calculated in the same manner as DB but with a different percentage rate.

[46] It is possible that the more bidders participate in an auction, the higher the chance that a bidder submits an aggressive (even predatory) bid that is low-price and low-quality. A more plausible explanation is that there is a variation of MSD rule taking place that discounts the quality score of non-best designers.

finding is that there is a strong positive relationship between the winner's quality advantage and its relative execution capacity ($REC^{QB}$). This is consistent with our intuition that a bidder with large capacity advantage is generally able to offer a superior design proposal than those that have small advantage. When it comes to delivery type, there is more variation in quality scores under TP than under DB because it puts more emphasis on the creativity in design and construction techniques. We also observe that the difference in quality scores is greater under Weighted Criteria than under other methods, which could be due to inherent differences in design evaluation and score computation between award algorithms.

The third column reports our main results for Equation $(1.a)$. Contract price is positively related to estimated price, as the cost and complexity of a project increases with its size. The coefficient for quality weight (under Weighted Criteria) is positive and significant because the marginal benefit of bidding slightly lower rises with the size of price weight. We assume that the owner chooses a large quality weight when the project is more challenging and technically specific, so bidders are induced to submit detailed design proposals with high price when the quality weight is high. The coefficient of number of bidders is negative and significant because increased participation fosters competition in price. The winner's quality advantage is positively correlated with contract price, consistent with intution that there is a positive feedback between price and quality. A bidder that submits high-quality design has more flexibility in choosing price because the marginal cost of bidding slightly higher decreases with the quality score difference, while a low-quality bidder that expects a quality disadvantage will submit a price bid of low markup in order to compensate for its weakness in design. The winner's backlog ratio is positively related to contract price, consistent with our expectations.[47] A bidder that anticipates a small backlog of orders is more eager to improve performance and thus bids more aggressively (lower price) to win a contract.

[47] Since a bidder's maximum backlog may not be a good measure of its maximum capacity level, we run the regression again using the standardized backlog (not reported), but it does not affect the substantive result (Jofre-Bonet and Pesendorfer, 2003).

Table 13. Regression results

| | (1)<br>$N$ | (2)<br>$T$ | (3)<br>$\ln(P)$ |
|---|---|---|---|
| Estimated price | 0.229*** | -1.675*** | 1.007*** |
| | (0.000) | (0.000) | (0.000) |
| Quality weight<br>(under Weighted Criteria) | -0.005 | -0.017 | 0.002*** |
| | (0.299) | (0.620) | (0.000) |
| Number of bidders | | 0.916** | -0.045*** |
| | | (0.022) | (0.000) |
| Winner quality advantage | | | 0.008*** |
| | | | (0.000) |
| Winner relative execution capacity | | 1.332*** | |
| | | (0.000) | |
| Winner past experience | | 0.936* | |
| | | (0.051) | |
| Winner backlog ratio | | | 0.049* |
| | | | (0.070) |
| Average backlog ratio<br>of qualified contractors | 0.261 | | |
| | (0.566) | | |
| CBSI | 0.003 | | 0.000 |
| | (0.265) | | (0.294) |
| <u>Base: Design-Build</u> | | | |
| Technical Proposal | -0.149 | 2.375** | -0.044** |
| | (0.287) | (0.015) | (0.023) |
| Alternative Bid | 0.207 | -0.003 | -0.022 |
| | (0.236) | (0.998) | (0.420) |
| <u>Base: Weighted Criteria</u> | | | |
| Independent scoring rule | -0.130 | -1.543 | 0.014 |
| | (0.316) | (0.102) | (0.566) |
| Region | Yes | Yes | Yes |
| Government | Yes | Yes | Yes |
| Construction subcategory | Yes | Yes | Yes |
| Constant | -0.446 | 19.618*** | -0.335*** |
| | (0.577) | (0.000) | (0.000) |
| Observations | 475 | 475 | 473 |
| Adj. R-squared | 0.097 | 0.113 | 0.984 |
| F-statistic | 4.21 | 3.54 | 1639.08 |

*Note.* P-values are in parentheses. *, **, and *** represent 10%, 5%, and 1% significance level, respectively.

We now assess the sensitivity of the results. We analyze 10 different scenarios: (A) allow the sample to include outliers; (B) restrict the sample to 2007-2012; (C) restrict the sample only to those under Weighted Criteria; (D) restrict the sample only to DB auctions; (E) use construction category dummies in place of subcategory dummies; (F) restrict the sample to those in the field of civil engineering and industrial equipment; (G) exclude the first-step estimation of quality advantage; (H) use the execution capacity variable relative to losers in place of qualified contractors; (I) eliminate condition (q.iv) when building a pool of qualified contractors; and (J) restrict the sample only to auctions in which bidders satisfy all of the four qualification requirements. Regression outcomes of these alternative model specifications and sample selections are shown in Appendix 1.C. Note that some variables lose signficiance when we change the composition of the sample. In the price estimation, the effect of the winner's backlog variable turns insignificant in (A), (B), (C), and (F), possibly because having a heavy workload might not be enough of a reason to bid cautiously when they can form bidding consortiums to share roles and responsibilities. Also, in (B), (D), (F), and (J), the two variables that measure bidder ability in the quality advantage estimation—specifically, relative capacity and past experience—have different size and significance of coefficients depending on the sample. We thus check the variance inflation factor (VIF) of the predictors in order to detect multicollinearity. None of the variables has a VIF above 5, indicating that there is no significant problem of multicollinearity.[48] In (G), when we do not consider quality advantage in the price equation, the model slightly underestimates the positive effect of project size and the negative effect of bidder participation. Otherwise, the general size and direction of variables remains consistent.

### *1.5.2 Counterfactual outcome*

For observations of collusive tendering, we estimate the number of bidders and the quality advantage expected to occur in the hypothetical scenario where there is no collusion. Table 14 shows the summary of the observed and estimated outcomes. The expected number of

[48] In the quality advantage estimation, winner's relative capacity and past experience have VIF of 1.59 and 1.94, respectively.

bidders is on average smaller under (I) and larger under (III) and (IV) compared to the actual values, and the expected quality advantage is almost half of the observed values under all collusion schemes. These are consistent with our hypotheses and show that when bidders engage in a collusive arrangement, they behave in a manner that deviates significantly from their behavior in a competitive environment.

Table 14. Summary of observed and predicted values

| | Variable | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|---|
| (I) price fixing | Number of bidders | 31 | 3.129 | 1.024 | 2 | 6 |
| | Expected $N$ $(\hat{N})$ | 31 | 2.711 | .277 | 2.016 | 3.352 |
| | Winner quality advantage | 31 | 8.065 | 5.165 | .342 | 18.128 |
| | Expected $T$ $(\hat{T})$ | 31 | 5.445 | 1.868 | 1.67 | 8.855 |
| (III) cover bidding | Number of bidders | 32 | 2.031 | .177 | 2 | 3 |
| | Expected $N$ $(\hat{N})$ | 32 | 2.542 | .241 | 2.193 | 3.206 |
| | Winner quality advantage | 32 | 11.536 | 4.76 | 4.29 | 23.292 |
| | Expected $T$ $(\hat{T})$ | 32 | 5.466 | 1.887 | 1.524 | 8.973 |
| (IV) market division | Number of bidders | 38 | 2.289 | .611 | 2 | 5 |
| | Expected $N$ $(\hat{N})$ | 38 | 2.71 | .237 | 2.375 | 3.122 |
| | Winner quality advantage | 38 | 9.747 | 4.422 | 2.761 | 20.573 |
| | Expected $T$ $(\hat{T})$ | 38 | 5.186 | 1.422 | 2.264 | 8.708 |

We replace the observed number of bidders and quality advantage with expected values, $\hat{N}$ and $\hat{T}$, respectively, and using the coefficient estimates in Table 13, we predict the competitive benchmark price $\tilde{P}$ of the 102 cases of collusion. We say that the difference between $\tilde{P}$ and the observed contract price is the amount of money unfairly transferred from the government to the bid riggers. An overcharge ratio is defined as the ratio of the damage amount to contract price, multiplied by 100%.

The counterfactual simulation suggests that under our baseline model specification, bid rigging generates an average price overcharge of 7.78%. This estimate is relatively greater than that of Lee et al. (2017), which use the dummy variable approach and include the observed values of $N$ and $T$ in the estimation of price. We believe that our two-stage method performs better than previous studies because it accounts for the effect of collusion on non-price elements of tendering and allows us to incorporate contractors' technical ability in the model. The estimated results from alternative model specifications (A)-(J) are reported in Appendix 1.D. When we limit the sample to auctions procured between 2007-2012, the overcharge ratio slightly increases to 8.10%. When we restrict the sample to auctions that adopt Weighted Criteria and those that adopt Design-Build, the average decreases to 7.45% (87 observations) and 6.52% (91 observations), respectively. When we run the regressions using construction category dummies (6 types) instead of subcategory dummies, it leads to a smaller overcharge of 7.29%. When we exclude projects in the field of architecture, it increases to 8.83% (100 observations). Overall, the mean overcharge ratio varies between 6.52%-8.83% across specifications, which draws a fairly consistent picture and provides evidence that collusive tendering causes substantial waste of taxpayer money.

The underlying assumption of our model is that a bidder's technical ability—measured by its relative execution capacity and past experience—is the key determinant of its quality advantage and hence its price bid. A contractor with high capacity and a relevant experience is likely to achieve a competitive position and submit high-quality design even in the absence of collusion, whereas an inexperienced contractor with low technical capacity is likely to stand a lower chance of winning when there is no collusive agreement to ensure its success. A low-ability bidder can therefore be induced to bid aggressively in terms of price in order to offset its potential disadvantage on the quality side. If we do not consider such differences in bidder ability when formulating counterfactual price, the model may underestimate the price when the winner is relatively superior to other potential contractors and overestimate the price when it is relatively inferior. In Table 15, we break down the cases by whether the winner is a top contractor (Panel A1), by project size (Panel A2), and by the type of collusion (Panel B). Panel A1 shows that the winning firm is a top contractor in 52 out of 102 cases, which are much larger in size than those received by a non-top contractor. In Panel A1 and A2, we report three types of overcharge ratios: (a) estimated using the baseline model specification, (b) estimated using the observed winner's quality advantage as opposed to $\hat{T}$, and (c) estimated without considering quality advantage in the price equation (see Appendix 1.C for full regression results). From the results, it is evident that there is a significant difference between (a) and (b), which is consistent with our expectation that using the observed quality score can overestimate counterfactual price and lead to underestimation of overcharge attributable to collusion. We also find that (a) is greater than (c) when the winner is not a top contractor (statistically significant at the 1% level), and (a) is slightly less than (c) when the winner is a top contractor (not statistically significant). This is consistent with our hypothesis that a model estimated without accounting for bidder ability would overestimate the price of non-top winners and underestimate the price of top winners. Since the discrepancy between (a) and (c) could be due to the difference in project size, we divide the projects based on their associated grade in Panel A2. We observe a consistent pattern, except for grade 1 contracts awarded to a top contractor. This could be due to the fact that large-scale projects tend to have large firms competing against large firms.[49] Aggressive quality competition between strong bidders can produce a relatively small $\hat{T}$, which is associated with a low counterfactual price.[50]

Table 15. Overcharge ratios

Panel A1. Overcharge ratios by winner's ranking

| Winner is Top 10 | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Expected $T$ $(\hat{T})$ | 52 | 5.428 | 1.531 | 2.241 | 8.708 |
| Overcharge ratios (%): | | | | | |
| (a) Baseline model | 52 | 8.043 | 4.034 | -1.198 | 14.226 |
| (b) Estimated using observed $T$ | 52 | 4.993 | 5.597 | -4.774 | 16.532 |
| (c) Estimated without $T$ | 52 | 8.051 | 4.173 | -.646 | 15.132 |
| Project value (1 billion KRW) | 52 | 178.793 | 99.806 | 50.984 | 384.715 |
| Winner execution capacity relative to qualified contractors | 52 | .401 | .652 | -.879 | 1.812 |
| **Winner is not Top 10** | **N** | **Mean** | **SD** | **Min** | **Max** |
| Expected $T$ $(\hat{T})$ | 50 | 5.284 | 1.872 | 1.524 | 8.973 |
| Overcharge ratios (%): | | | | | |
| (a) Baseline model | 50 | 7.495 | 4.417 | -1.859 | 15.442 |
| (b) Estimated using observed $T$ | 50 | 3.851 | 5.603 | -11.683 | 13.415 |
| (c) Estimated without $T$ | 50 | 7.118 | 4.229 | -3.5 | 15.12 |
| Project value (1 billion KRW) | 50 | 52.555 | 46.407 | 4.695 | 243.073 |
| Winner execution capacity relative to qualified contractors | 50 | -.508 | .934 | -2.024 | 1.423 |

[49] The ratio of top contractors to actual bidders is on average 0.88 in Grade 1 projects when the winner is a top contractor.

[50] When the winner is a top contractor, the expected quality advantage is 5.109, 5.497, and 6.362 in Grade 1, 2, and 3, respectively.

Panel A2. Overcharge ratios by project size

| Grade | Winner is Top 10 | | | | Winner is not Top 10 | | | |
|---|---|---|---|---|---|---|---|---|
| | N | (a) | (b) | (c) | N | (a) | (b) | (c) |
| Grade 1 | 27 | 7.077 | 2.696 | 6.74 | 2 | 2.876 | -1.896 | 2.164 |
| Grade 2 | 17 | 9.929 | 8.054 | 10.105 | 6 | 8.2 | 3.574 | 7.677 |
| Grade 3 | 8 | 7.296 | 6.241 | 8.113 | 14 | 8.016 | 4.133 | 7.605 |
| Grade 4, 5, 6, 7 | | | | | 28 | 7.413 | 4.179 | 7.108 |

*Note.* Projects are classified into seven grades, with Grade 1 being the highest. See Table 8 for the range of project size associated with each grade.

Panel B. Overcharge ratios by collusion type (%)

| | N | Mean | Min | Max | Grouped mean |
|---|---|---|---|---|---|
| All | 102 | 7.774 | -1.859 | 15.442 | 7.833 |
| (I) price fixing | 31 | 6.791 | -1.859 | 13.354 | 6.791 |
| (III) cover bidding | 32 | 6.972 | -.348 | 14.226 | 6.941 |
| - *Unilateral cover bidding* | 20 | 6.801 | -.348 | 14.226 | 6.801 |
| - *Cross-cover bidding* | 12 | 7.256 | .655 | 11.462 | 7.174 |
| (IV) market division | 38 | 9.286 | -1.198 | 15.442 | 9.471 |
| - *Unilateral cover bidding* | 20 | 10.128 | 1.417 | 15.442 | 9.933 |
| - *Cross-cover bidding* | 18 | 8.351 | -1.198 | 14.212 | 8.956 |

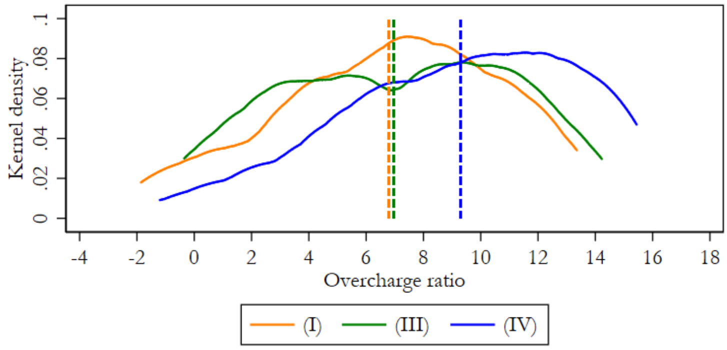
*Note.* An overcharge ratio is defined as the ratio of the estimated damage amount to contract price, multiplied by 100%. The rightmost column displays the average overcharge ratio after grouping.

Panel B of Table 15 reports the overcharge ratio of different types of bid rigging, specifically, (I) price fixing, (III) cover bidding, and (IV) market division. The average ratio is increasing in the order of (I), (III), and (IV), although a wide range of estimates is observed for all three schemes as illustrated in Figure 2. Note that in the case of (III) and (IV), there are instances of collusive arrangement spanning over multiple projects, and the damage caused on these projects might need to be calculated jointly. We thus divide the cases of (IV) into four clusters (see footnote 26) and group them together if there is bid rotation and put the cases of (III) into pairs if there is cross-cover bidding. We found six pairs of (III) XCB (12 observations) and four groups of (IV) XCB (18 observations).[51] The

[51] UCB and XCB refer to unilateral cover bidding and cross-cover bidding, respectively.

last column of Panel B reports the mean overcharge ratio after organizing the projects into groups and pairs. The estimates of (III) and (IV) slightly change, but the overall pattern is consistent.

Figure 2. Kernel density estimation of overcharge ratios




*Note*. The solid lines are the kernel density estimation of overcharge ratios for each bid rigging type. Kernel density estimation is a non-parametric method of estimating the probability density function. We use the Epanechnikov kernel function to smooth data. The dashed lines indicate the mean overcharge ratio of each type.

Table 16. Overcharge ratios in order of size under different specifications

| Model specification | Mean overcharge ratios |
|---|---|
| Baseline model | (I), (III) UCB, (III) XCB, (IV) XCB, (IV) UCB |
| A. Including outliers | (III) UCB, (I), (III) XCB, (IV) UCB, (IV) XCB |
| B. 2007-2012 | (III) XCB, (III) UCB, (I), (IV) XCB, (IV) UCB |
| C. Weighted Criteria | (III) XCB, (III) UCB, (I), (IV) XCB, (IV) UCB |
| D. Design Build | (III) UCB, (I), (III) XCB, (IV) XCB, (IV) UCB |
| E. Category dummies | (III) UCB, (III) XCB, (I), (IV) XCB, (IV) UCB |
| F. Field (ii), (iii) | (III) UCB, (I), (III) XCB, (IV) UCB, (IV) XCB |
| G. Without $T$ | (I), (III) UCB, (III) XCB, (IV) XCB, (IV) UCB |
| H. Using $REC^B$ | (III) UCB, (I), (III) XCB, (IV) XCB, (IV) UCB |
| I. Without (q.iv) | (III) UCB, (I), (III) XCB, (IV) XCB, (IV) UCB |
| J. Qualified bidders only | (I), (III) UCB, (III) XCB, (IV) XCB, (IV) UCB |

*Note*. UCB and XCB refer to unilateral cover bidding and cross-cover bidding, respectively.

We perform the same analysis with alternative model specifications (A)-(J) and, in Table 16, list the bid rigging types in ascending order of size of mean overcharge ratios (see Appendix 1.D for full results). Overall, we do not observe a systematic pattern. As bid riggers decide on a target price considering various factors, such as who is involved in the scheme and what their goals and stakes are for sticking to the agreement, there is a wide range of possible outcomes regardless of the type of collusion. One general observation that can be made from the results is that the overcharge ratio is generally higher when the scheme stretches over multiple projects. That is, it appears that bid riggers seek higher profits from the contract when they engage in collusion through cross-cover bidding and market division. One explanation could be that when conspirators collude over multiple events, they are able to establish a solid, long-lasting relationship and strike a more profitable deal because there is an increased threat of punishment for deviation. They have higher stakes at risk because, if caught, they can face double punishment, first for undertaking a project unlawfully and second for acting as a designated loser for another bidder. More research is necessary to confirm this theory.

Lastly, we review how the bid rigging cases are handled in practice. The KFTC calculates the base fine amount by multiplying a fixed percentage (7-10%) to the relevant sales of collusion.[52] Conspirators are granted reduction of fines, taking into account their cooperation, financial inability, and other circumstances. Table 17 presents the base percentage applied by the KFTC and motives declared by the bid riggers for engaging in each type of collusion. Note that a high percentage (10%) is applied more commonly under (I) than under (III) and (IV), contrary to our expectation.[53] To understand the source of the discrepancy, we examine the incentives and timing of collusive agreements. More than half of the reports on (III) and (IV) schemes mention that conspirators were worried of having the auction declared invalid for having fewer than two bidders. When there is a high chance of auction failure, an interested bidder may be compelled to invite a cover

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[52] The relevant sales of a collusive agreement is generally the successful bidder's contract price. The same amount is applied to conspirators who did not receive the contract (such as complementary bidders), but they usually receive a 50% reduction in their fines.

[53] The actual fines imposed on the conspirators of (IV) are likely to be massive because a market division scheme usually takes place in large projects.

bidder to make up for the lack of supply and to win the auction successfully.[54] Bid riggers also claim that in the case of (IV), the "one firm, one project" policy created a market environment that encouraged bidders to engage in tacit or explicit collusion.[55] Under this policy, construction firms could not be awarded more than one contract in a group of projects procured together, making it difficult for them to decide which auction to participate and bid. As for scheme (I), several KFTC reports mention that bidders were worried about the financial feasibility of the project and wanted to prevent having an unprofitable price war. Yet, this claim seems to lack credibility because, although conspirators typically decide on their price bids close to the auction day, the scheme is usually established early in stage (for example, after on-site orientation), which is likely to be before completing the cost-benefit analysis. These arguments, which we are unable to take into account in our overcharge estimation, seem to have affected the determination of fine amounts in practice.

Table 17. Base percentage for surcharge calculation
and motivation for collusion

| Alleged behavior | N | Base percentage | Motivation claimed by conspirators |
|---|---|---|---|
| (I) Price fixing | 34 | 7% (3 cases),<br>10% (31 cases) | Avoid price dumping;<br>low revenue to expense ratio |
| (II) Design distortion | 1 | 5% (1 case) | Avoid excessive design competition |
| (III) Cover bidding | 35 | 7% (10 cases),<br>10% (25 cases) | Prevent auction failure |
| (IV) Market division | 38 | 7% (23 cases),<br>10% (15 cases) | Prevent auction failure;<br>"one firm, one project" rule |

*Note.* The base surcharge amount is calculated as the value of relevant sales multiplied by the percentage base. A reduction of fines is granted considering the individual circumstances of conspirators.

54 To check the validity of this argument, we compare the number of PQ applicants to actual bidders. When there is no bid rigging, the number of firms that apply for PQ evaluation matches with the actual number of bidders in 169 out of 254 cases (see footnote 34). When there is collusion, the numbers match in 11 out of 20 cases of (I), all 9 cases of (III) UCB, all 4 cases of (III) XCB, 14 out of 16 cases of (IV) UCB, and 12 out of 16 cases of (IV) XCB. The fact that no other contractor showed interest in many of the projects under (III) and (IV) in the PQ stage seems to support the argument.

55 The policy generated strong negative reactions until it was abolished in 2015.

## 1.6 Conclusion

The objective of public procurement is to deliver goods and services in a cost-effective, high quality, and timely manner. Yet, tendering can result in the opposite of the aims and incentives of the buyer when bidders agree to exchange and coordinate their bids. Three forms of collusion are possible in a two-dimensional procurement auction: fixing of price, fixing of quality, or fixing of both. When bidders engineer their bids to eliminate any competition, as in the case of (III) cover bidding and (IV) market division, who wins the auction at what price and quality depends solely on the specification of the collusive agreement. A one-sided fixing scheme such as (I) price fixing also leads to an auction outcome inferior to the one under competitive tendering because it does not achieve the best value for money. These collusion schemes can distort the auction outcome such that an incompetent bidder is awarded a contract and have negative consequences such as poor quality of design and waste of public funds.

The purpose of the present study is to quantify the harm caused by bid rigging in the context of public procurement of construction projects in Korea. This topic has been addressed by other researchers (Lee and Hahn, 2002; Lee et al., 2017), but previous studies have failed to consider the potential effect of collusion on non-price elements of procurement. We are particularly interested in two variables—number of bidders and winner’s quality advantage. We thus propose a two-stage forecasting method that can account for the missing data of such variables in the counterfactual situation. Specifically, in the first stage, we use observations of non-collusive auctions to estimate the regression equation of the two variables of interest, and then we predict their expected values if there were no bid rigging for collusive auctions. In the second stage, we estimate the price equation using non-collusive auctions, and we substitute the observed values by the estimates obtained in the first stage when predicting the counterfactual price of collusion. The difference between the counterfactual price and the observed contract price is the additional amount of money unlawfully transferred from the government to the bid riggers.

The counterfactual analysis reveals that the government has suffered an average overcharge of 7.78% in the 102 cases of collusion between 2008-2012. This indicates that more than 850 billion KRW of taxpayer money has been wasted because of bid rigging. Based on the results, we make two general observations. First, the two-stage forecasting method allows us to consider variables such as bidder ability and relative quality score in the model and to construct the hypothetical competitive scenario in a more a reliable manner. If we fail to consider these variables in the price equation, the model may underestimate the counterfactual price when the winner is relatively superior to other potential contractors and overestimate the price when it is relatively inferior. Second, when the cases of bid rigging are broken down by their collusive nature, we find that the overcharge ratio is generally higher when the collusion scheme stretches over multiple projects. This could be due to the differences in the commitments that the conspirators must make to engage in the schemes.

# Appendix 1

Appendix 1.A

The table below explains key steps in tender process.

| Phase | Description |
|---|---|
| Tender notice | Determine type and method of contract based on project characteristics and publish tender notice |
| PQ evaluation | Companies are evaluated on their experience and performance on similar contracts, financial and technical capabilities, etc. |
| Explanation at site | Qualified contractors are requested to participate in a site orientation |
| Tendering | Qualified contractors submit price and quality bids, and evaluation panel evaluates proposals |
| Contract award | A successful bidder is selected and the contract is concluded |

Appendix 1.B

In the collusion regime, there are two cases in which the winner does not have the best design. One case is the fixing of price to just below 95% of the estimated price (Type I). The bidder with the second-best price and the second-best design is awarded the contract.

First case: price fixing (I)

| Weight (50:50) | Ratio of contract price to estimated price | Price rank | Quality score | Quality rank | Total score | Total rank |
|---|---|---|---|---|---|---|
| Bidder A | 94.79% | 2 | 85.16 | 2 | 92.57 | 1 |
| Bidder B | 94.85% | 3 | 85.21 | 1 | 92.56 | 2 |
| Bidder C | 94.76% | 1 | 84.53 | 3 | 92.27 | 3 |

The other case is found guilty of a market division scheme (Type IV). At first, the KFTC did not charge Bidder A (the designated winner) with collusion because during the investigation, it appeared that the bid rigging scheme was established only between Bidder B and C (and failed); yet, the High Court later ruled that Bidder A was also part of the scheme, having agreed with Bidder B to allocate projects to each other.

Second case: market division (IV)

| Weight (40:60) | Ratio of contract price to estimated price | Price rank | Quality score | Quality rank | Total score | Total rank |
|---|---|---|---|---|---|---|
| Bidder A | 92.00% | 1 | 86.95 | 2 | 92.17 | 1 |
| Bidder B | 99.50% | 3 | 90.37 | 1 | 91.20 | 2 |
| Bidder C | 94.90% | 2 | 78.34 | 3 | 85.78 | 3 |

Appendix 1.C

| | Panel A. Including outliers | | | Panel B. 2007-2012 | | |
|---|---|---|---|---|---|---|
| | (1) $N$ | (2) $T$ | (3) $\ln(P)$ | (1) $N$ | (2) $T$ | (3) $\ln(P)$ |
| Estimated price | 0.223*** | -1.894*** | 1.006*** | 0.267*** | -1.830*** | 1.006*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Quality weight (under Weighted Criteria) | -0.007 | -0.027 | 0.003*** | -0.006 | 0.010 | 0.002*** |
| | (0.121) | (0.441) | (0.000) | (0.354) | (0.766) | (0.002) |
| Number of bidders | | 1.187*** | -0.051*** | | 0.981** | -0.046*** |
| | | (0.005) | (0.000) | | (0.018) | (0.000) |
| Winner quality advantage | | | 0.008*** | | | 0.008*** |
| | | | (0.000) | | | (0.000) |
| Winner relative execution capacity | | 1.435*** | | | 1.556*** | |
| | | (0.000) | | | (0.000) | |
| Winner past experience | | 1.147** | | | 0.467 | |
| | | (0.018) | | | (0.312) | |
| Winner backlog ratio | | | 0.016 | | | 0.008 |
| | | | (0.624) | | | (0.779) |
| Average backlog ratio of qualified contractors | 0.226 | | | 0.795 | | |
| | (0.617) | | | (0.210) | | |
| CBSI | 0.003 | | 0.000 | 0.003 | | 0.000 |
| | (0.159) | | (0.566) | (0.204) | | (0.290) |
| <u>Base: Design-Build</u> | | | | | | |
| Technical Proposal | -0.129 | 2.433** | -0.050** | -0.185 | 0.867 | -0.103*** |
| | (0.350) | (0.013) | (0.018) | (0.558) | (0.512) | (0.007) |
| Alternative Bid | 0.264 | 1.111 | -0.013 | 0.325* | -0.283 | -0.018 |
| | (0.126) | (0.349) | (0.665) | (0.096) | (0.792) | (0.520) |
| <u>Base: Weighted Criteria</u> | | | | | | |
| Independent scoring rule | -0.158 | -1.432 | 0.031 | -0.045 | -1.387 | -0.009 |
| | (0.219) | (0.126) | (0.248) | (0.761) | (0.114) | (0.723) |
| Region | Yes | Yes | Yes | Yes | Yes | Yes |
| Government | No | No | No | No | No | No |
| Construction subcategory | Yes | Yes | Yes | Yes | Yes | Yes |
| Constant | -0.258 | 22.186*** | -0.316*** | -0.860 | 22.580*** | -0.236** |
| | (0.744) | (0.000) | (0.003) | (0.436) | (0.000) | (0.016) |
| Observations | 492 | 492 | 490 | 361 | 361 | 359 |
| Adj. R-squared | 0.100 | 0.120 | 0.974 | 0.078 | 0.123 | 0.985 |
| F-statistic | 4.36 | 3.55 | 1181.94 | 3.81 | 3.26 | 1535.77 |

*Note.* P-values are in parentheses. *, **, and *** represent 10%, 5%, and 1% significance level, respectively. Panel A displays the results when the 17 cases of outliers are not excluded from the sample. In Panel B, the models are estimated using a narrower time window (2007-2012) because there can be undetected or unpunished cases of collusion since 2012.

| | Panel C. Weighted Criteria | | | Panel D. Design Build | | |
|---|---|---|---|---|---|---|
| | (1) $N$ | (2) $T$ | (3) $\ln(P)$ | (1) $N$ | (2) $T$ | (3) $\ln(P)$ |
| Estimated price | 0.210*** | -1.734*** | 1.003*** | 0.281*** | -1.713*** | 1.014*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Quality weight (under Weighted Criteria) | -0.005 | -0.018 | 0.002*** | -0.008 | 0.002 | 0.002*** |
| | (0.359) | (0.607) | (0.000) | (0.213) | (0.954) | (0.003) |
| Number of bidders | | 1.010** | -0.041*** | | 0.961** | -0.055*** |
| | | (0.013) | (0.000) | | (0.041) | (0.000) |
| Winner quality advantage | | | 0.007*** | | | 0.009*** |
| | | | (0.000) | | | (0.000) |
| Winner relative execution capacity | | 1.259*** | | | 1.540*** | |
| | | (0.000) | | | (0.000) | |
| Winner past experience | | 1.047** | | | 0.639 | |
| | | (0.047) | | | (0.198) | |
| Winner backlog ratio | | | 0.042 | | | 0.073*** |
| | | | (0.130) | | | (0.010) |
| Average backlog ratio of qualified contractors | 0.278 | | | 0.846 | | |
| | (0.557) | | | (0.144) | | |
| CBSI | 0.001 | | 0.001 | 0.001 | | 0.000 |
| | (0.667) | | (0.149) | (0.638) | | (0.480) |
| Base: Design-Build | | | | | | |
| Technical Proposal | -0.147 | 2.436** | -0.039** | | | |
| | (0.305) | (0.013) | (0.043) | | | |
| Alternative Bid | 0.197 | -0.120 | -0.026 | | | |
| | (0.265) | (0.904) | (0.335) | | | |
| Base: Weighted Criteria | | | | | | |
| Independent scoring rule | | | | -0.165 | -0.947 | 0.004 |
| | | | | (0.258) | (0.303) | (0.867) |
| Region | Yes | Yes | Yes | Yes | Yes | Yes |
| Government | Yes | Yes | Yes | Yes | Yes | Yes |
| Construction subcategory | Yes | Yes | Yes | Yes | Yes | Yes |
| Constant | -0.158 | 20.035*** | -0.307*** | -1.344 | 22.987*** | -0.285*** |
| | (0.847) | (0.000) | (0.001) | (0.192) | (0.000) | (0.003) |
| Observations | 437 | 437 | 435 | 357 | 357 | 355 |
| Adj. R-squared | 0.088 | 0.101 | 0.983 | 0.099 | 0.148 | 0.987 |
| F-statistic | 3.96 | 3.56 | 1587.82 | 6.74 | 3.26 | 1682.80 |

*Note.* P-values are in parentheses. *, **, and *** represent 10%, 5%, and 1% significance level, respectively. In Panel C, the sample is restricted to auctions that adopt the Weighted Criteria algorithm, and in Panel D, it includes only DB auctions.

| | Panel E. Construction category | | | Panel F. Exclude architecture | | |
|---|---|---|---|---|---|---|
| | (1) $N$ | (2) $T$ | (3) $\ln(P)$ | (1) $N$ | (2) $T$ | (3) $\ln(P)$ |
| Estimated price | 0.237*** | -1.698*** | 1.006*** | 0.308*** | -0.905 | 1.006*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.133) | (0.000) |
| Quality weight (under Weighted Criteria) | -0.006 | -0.003 | 0.002*** | -0.007 | 0.036 | 0.005*** |
| | (0.205) | (0.916) | (0.000) | (0.470) | (0.506) | (0.000) |
| Number of bidders | | 0.814** | -0.044*** | | 0.580 | -0.073*** |
| | | (0.035) | (0.000) | | (0.234) | (0.000) |
| Winner quality advantage | | | 0.008*** | | | 0.013*** |
| | | | (0.000) | | | (0.000) |
| Winner relative execution capacity | | 1.333*** | | | 1.597*** | |
| | | (0.000) | | | (0.001) | |
| Winner past experience | | 0.839* | | | 0.870 | |
| | | (0.051) | | | (0.170) | |
| Winner backlog ratio | | | 0.053** | | | 0.028 |
| | | | (0.048) | | | (0.511) |
| Average backlog ratio of qualified contractors | 0.262 | | | 0.100 | | |
| | (0.558) | | | (0.876) | | |
| CBSI | 0.002 | | 0.000 | 0.002 | | 0.000 |
| | (0.308) | | (0.371) | (0.496) | | (0.627) |
| Base: Design-Build | | | | | | |
| Technical Proposal | -0.121 | 2.385** | -0.040** | 0.021 | 3.730* | -0.009 |
| | (0.371) | (0.015) | (0.036) | (0.909) | (0.050) | (0.825) |
| Alternative Bid | 0.238 | 0.190 | -0.021 | 0.216 | 0.138 | -0.015 |
| | (0.170) | (0.841) | (0.438) | (0.240) | (0.893) | (0.596) |
| Base: Weighted Criteria | | | | | | |
| Independent scoring rule | -0.142 | -1.846* | 0.017 | -0.070 | -0.858 | 0.038 |
| | (0.238) | (0.060) | (0.465) | (0.681) | (0.505) | (0.252) |
| Region | Yes | Yes | Yes | Yes | Yes | Yes |
| Government | Yes | Yes | Yes | Yes | Yes | Yes |
| Construction subcategory | No | No | No | Yes | Yes | Yes |
| Constant | -0.187 | 17.253*** | -0.370*** | -1.131 | 6.144 | -0.399** |
| | (0.816) | (0.000) | (0.000) | (0.414) | (0.436) | (0.036) |
| Observations | 474 | 474 | 472 | 265 | 265 | 265 |
| Adj. R-squared | 0.092 | 0.126 | 0.984 | 0.097 | 0.059 | 0.977 |
| F-statistic | 5.03 | 4.28 | 1973.72 | 3.96 | 2.37 | 582.21 |

*Note.* P-values are in parentheses. *, **, and *** represent 10%, 5%, and 1% significance level, respectively. In Panel E, construction category dummies (6 types) are used instead of the subcategory dummies (11 types). In Panel F, the sample is limited to projects in the field of civil engineering and industrial equipment.

| | Panel G. Quality advantage estimation | | Panel H. Relative execution capacity | |
|---|---|---|---|---|
| | | Excluded | | Relative to losers |
| | $\ln(P)$ | $\ln(P)$ | $T$ | $T$ |
| Estimated price | 1.007*** | 0.997*** | -1.675*** | -1.280*** |
| | (0.000) | (0.000) | (0.000) | (0.001) |
| Quality weight (under Weighted Criteria) | 0.002*** | 0.002*** | -0.017 | -0.029 |
| | (0.000) | (0.000) | (0.620) | (0.383) |
| Number of bidders | -0.045*** | -0.038*** | 0.916** | 0.980** |
| | (0.000) | (0.000) | (0.022) | (0.013) |
| Winner quality advantage | 0.008*** | | | |
| | (0.000) | | | |
| Difference in execution capacity between winner and qualified contractors | | | 1.332*** | |
| | | | (0.000) | |
| Difference in execution capacity between winner and losers | | | | 1.249*** |
| | | | | (0.000) |
| Winner past experience | | | 0.936* | 1.297*** |
| | | | (0.051) | (0.005) |
| Winner backlog ratio | 0.049* | 0.052* | | |
| | (0.070) | (0.092) | | |
| Average backlog ratio of qualified contractors | | | | |
| CBSI | 0.000 | 0.000 | | |
| | (0.294) | (0.399) | | |
| <u>Base: Design-Build</u> | | | | |
| Technical Proposal | -0.044** | -0.023 | 2.375** | 2.286** |
| | (0.023) | (0.238) | (0.015) | (0.017) |
| Alternative Bid | -0.022 | -0.022 | -0.003 | -0.059 |
| | (0.420) | (0.439) | (0.998) | (0.954) |
| <u>Base: Weighted Criteria</u> | | | | |
| Independent scoring rule | 0.014 | -0.004 | -1.543 | -2.781*** |
| | (0.566) | (0.877) | (0.102) | (0.006) |
| Region | Yes | Yes | Yes | Yes |
| Government | Yes | Yes | Yes | Yes |
| Construction subcategory | Yes | Yes | Yes | Yes |
| Constant | -0.335*** | -0.211** | 19.618*** | 15.994*** |
| | (0.000) | (0.024) | (0.000) | (0.001) |
| Observations | 473 | 473 | 475 | 473 |
| Adj. R-squared | 0.984 | 0.981 | 0.113 | 0.125 |
| F-statistic | 1639.08 | 1530.12 | 3.54 | 4.08 |

*Note.* P-values are in parentheses. *, **, and *** represent 10%, 5%, and 1% significance level, respectively. In Panel G, winner's quality advantage is not considered in the price model. In Panel H, $REC^B$ is used instead of $REC^{QC}$ in the quality advantage model.

| | Panel I. Without (q.iv) | | | Panel J. Qualified bidders | | |
|---|---|---|---|---|---|---|
| | (1)<br>$N$ | (2)<br>$T$ | (3)<br>$\ln(P)$ | (1)<br>$N$ | (2)<br>$T$ | (3)<br>$\ln(P)$ |
| Estimated price | 0.231*** | -2.180*** | 1.007*** | 0.263*** | -1.729*** | 1.015*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Quality weight<br>(under Weighted Criteria) | -0.005 | -0.035 | 0.002*** | -0.008 | 0.027 | 0.001* |
| | (0.302) | (0.297) | (0.000) | (0.170) | (0.464) | (0.082) |
| Number of bidders | | 0.921** | -0.045*** | | 1.087** | -0.051*** |
| | | (0.020) | (0.000) | | (0.022) | (0.000) |
| Winner quality advantage | | | 0.008*** | | | 0.008*** |
| | | | (0.000) | | | (0.000) |
| Winner relative execution capacity | | 1.173*** | | | 1.368*** | |
| | | (0.000) | | | (0.001) | |
| Winner past experience | | 1.017** | | | 0.505 | |
| | | (0.035) | | | (0.506) | |
| Winner backlog ratio | | | 0.049* | | | 0.052* |
| | | | (0.070) | | | (0.083) |
| Average backlog ratio<br>of qualified contractors | -0.311 | | | 0.113 | | |
| | (0.667) | | | (0.842) | | |
| CBSI | 0.003 | | 0.000 | 0.002 | | 0.001 |
| | (0.212) | | (0.294) | (0.474) | | (0.202) |
| <u>Base: Design-Build</u> | | | | | | |
| Technical Proposal | -0.147 | 2.251** | -0.044** | -0.309** | 1.805 | -0.072*** |
| | (0.293) | (0.021) | (0.023) | (0.016) | (0.103) | (0.001) |
| Alternative Bid | 0.208 | 0.050 | -0.022 | 0.272 | -1.164 | 0.004 |
| | (0.231) | (0.960) | (0.420) | (0.196) | (0.336) | (0.885) |
| <u>Base: Weighted Criteria</u> | | | | | | |
| Independent scoring rule | -0.137 | -1.899** | 0.014 | -0.007 | -2.097 | -0.006 |
| | (0.293) | (0.042) | (0.566) | (0.969) | (0.141) | (0.869) |
| Region | Yes | Yes | Yes | Yes | Yes | Yes |
| Government | Yes | Yes | Yes | Yes | Yes | Yes |
| Construction subcategory | Yes | Yes | Yes | Yes | Yes | Yes |
| Constant | -0.110 | 26.915*** | -0.335*** | -0.306 | 16.927*** | -0.323*** |
| | (0.889) | (0.000) | (0.000) | (0.753) | (0.002) | (0.004) |
| Observations | 475 | 475 | 473 | 342 | 342 | 341 |
| Adj. R-squared | 0.097 | 0.115 | 0.984 | 0.127 | 0.103 | 0.983 |
| F-statistic | 4.24 | 3.52 | 1639.08 | 3.94 | 2.70 | 1092.56 |

*Note.* P-values are in parentheses. *, **, and *** represent 10%, 5%, and 1% significance level, respectively. Panel I displays results when the qualified contractor pool is built without condition (q.iv). In Panel J, the sample is restricted to those in which bidders satisfy all of the four qualification requirements.

Appendix 1.D

Comparison of overcharge estimates across specifications

Baseline model specification
(estimated with 475 non-collusive observations)

| | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| All | 102 | 7.774 | 4.214 | -1.859 | 15.442 |
| (I) price fixing | 31 | 6.791 | 4.066 | -1.859 | 13.354 |
| (III) cover bidding | 32 | 6.972 | 4.071 | -.348 | 14.226 |
| - *Unilateral cover bidding* | 20 | 6.801 | 4.48 | -.348 | 14.226 |
| - *Cross-cover bidding* | 12 | 7.256 | 3.447 | .655 | 11.462 |
| (IV) market division | 38 | 9.286 | 4.175 | -1.198 | 15.442 |
| - *Unilateral cover bidding* | 20 | 10.128 | 4.462 | 1.417 | 15.442 |
| - *Cross-cover bidding* | 18 | 8.351 | 3.732 | -1.198 | 14.212 |

A. Including outliers
(estimated with 492 non-collusive observations)

| | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| All | 102 | 9.916 | 3.515 | .179 | 17.423 |
| (I) price fixing | 31 | 9.532 | 4.124 | .179 | 16.304 |
| (III) cover bidding | 32 | 9.303 | 3.386 | .818 | 14.447 |
| - *Unilateral cover bidding* | 20 | 8.722 | 3.827 | .818 | 14.447 |
| - *Cross-cover bidding* | 12 | 10.272 | 2.32 | 6.336 | 13.302 |
| (IV) market division | 38 | 10.767 | 3.02 | 2.11 | 17.423 |
| - *Unilateral cover bidding* | 20 | 10.701 | 3.082 | 4.92 | 16.82 |
| - *Cross-cover bidding* | 18 | 10.841 | 3.037 | 2.11 | 17.423 |

B. Time window 2007-2012
(estimated with 361 non-collusive observations)

| | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| All | 102 | 8.096 | 4.9 | -6.007 | 16.9 |
| (I) price fixing | 31 | 7.021 | 5.26 | -2.84 | 14.997 |
| (III) cover bidding | 32 | 6.694 | 4.782 | -6.007 | 13.155 |
| - *Unilateral cover bidding* | 20 | 6.951 | 5.234 | -6.007 | 13.155 |
| - *Cross-cover bidding* | 12 | 6.266 | 4.099 | .157 | 11.751 |
| (IV) market division | 38 | 10.15 | 4.115 | 1.197 | 16.9 |
| - *Unilateral cover bidding* | 20 | 10.711 | 4.746 | 1.197 | 16.9 |
| - *Cross-cover bidding* | 18 | 9.528 | 3.302 | 1.374 | 14.764 |

C. Weighted Criteria
(estimated with 437 non-collusive observations)

| | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| All | 87 | 7.448 | 4.17 | -1.291 | 14.773 |
| (I) price fixing | 28 | 6.619 | 3.81 | -1.291 | 13.025 |
| (III) cover bidding | 20 | 5.884 | 4.028 | .182 | 13.782 |
| - *Unilateral cover bidding* | 14 | 6.201 | 4.26 | .498 | 13.782 |
| - *Cross-cover bidding* | 6 | 5.142 | 3.68 | .182 | 9.571 |
| (IV) market division | 38 | 8.908 | 4.176 | -.914 | 14.773 |
| - *Unilateral cover bidding* | 20 | 9.759 | 4.56 | .646 | 14.773 |
| - *Cross-cover bidding* | 18 | 7.963 | 3.593 | -.914 | 13.746 |

D. Design Build
(estimated with 357 non-collusive observations)

| | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| All | 91 | 6.519 | 5.511 | -5.328 | 17.855 |
| (I) price fixing | 27 | 5.764 | 4.491 | -2.883 | 14.327 |
| (III) cover bidding | 31 | 5.964 | 5.114 | -3.18 | 16.423 |
| - *Unilateral cover bidding* | 19 | 5.602 | 5.754 | -1.794 | 16.423 |
| - *Cross-cover bidding* | 12 | 6.538 | 4.068 | -3.18 | 11.072 |
| (IV) market division | 32 | 7.791 | 6.572 | -5.328 | 17.855 |
| - *Unilateral cover bidding* | 14 | 8.867 | 7.552 | -1.674 | 17.855 |
| - *Cross-cover bidding* | 18 | 6.954 | 5.782 | -5.328 | 16.308 |

E. Construction category dummies
(estimated with 474 non-collusive observations)

| | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| All | 102 | 7.29 | 3.492 | -1.167 | 13.787 |
| (I) price fixing | 31 | 6.758 | 3.592 | -.448 | 12.163 |
| (III) cover bidding | 32 | 6.441 | 3.318 | -.062 | 12.568 |
| - *Unilateral cover bidding* | 20 | 6.324 | 3.735 | -.062 | 12.568 |
| - *Cross-cover bidding* | 12 | 6.636 | 2.619 | 1.082 | 9.869 |
| (IV) market division | 38 | 8.454 | 3.369 | -1.167 | 13.787 |
| - *Unilateral cover bidding* | 20 | 8.925 | 3.436 | 1.978 | 13.787 |
| - *Cross-cover bidding* | 18 | 7.93 | 3.309 | -1.167 | 13.332 |

F. Civil engineering and industrial equipment
(estimated with 265 non-collusive observations)

| | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| All | 100 | 8.831 | 4.541 | -5.457 | 17.86 |
| (I) price fixing | 30 | 8.249 | 5.384 | -4.348 | 16.582 |
| (III) cover bidding | 31 | 8.342 | 4.439 | -5.457 | 13.678 |
| - *Unilateral cover bidding* | 19 | 7.81 | 5.181 | -5.457 | 13.678 |
| - *Cross-cover bidding* | 12 | 9.184 | 2.923 | 4.266 | 12.284 |
| (IV) market division | 38 | 9.729 | 3.888 | -.922 | 17.86 |
| - *Unilateral cover bidding* | 20 | 9.277 | 4.102 | 1.12 | 17.86 |
| - *Cross-cover bidding* | 18 | 10.231 | 3.686 | -.922 | 17.26 |

G. Without quality advantage ($T$) estimation
(estimated with 475 non-collusive observations)

| | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| All | 102 | 7.594 | 4.206 | -3.5 | 15.132 |
| (I) price fixing | 31 | 6.47 | 3.962 | -3.5 | 12.36 |
| (III) cover bidding | 32 | 6.863 | 3.929 | -.196 | 14.104 |
| - *Unilateral cover bidding* | 20 | 6.775 | 4.333 | .015 | 14.104 |
| - *Cross-cover bidding* | 12 | 7.009 | 3.323 | -.196 | 10.876 |
| (IV) market division | 38 | 9.154 | 4.308 | -.646 | 15.132 |
| - *Unilateral cover bidding* | 20 | 9.895 | 4.591 | .897 | 15.12 |
| - *Cross-cover bidding* | 18 | 8.33 | 3.934 | -.646 | 15.132 |

H. Using winner execution capacity relative to losers
(estimated with 475 non-collusive observations)

| | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| All | 101 | 6.878 | 4.737 | -3.105 | 15.222 |
| (I) price fixing | 31 | 6.4 | 3.741 | -1.122 | 13.288 |
| (III) cover bidding | 32 | 6.247 | 4.752 | -2.4 | 14.514 |
| - *Unilateral cover bidding* | 20 | 5.986 | 5.046 | -1.303 | 14.514 |
| - *Cross-cover bidding* | 12 | 6.682 | 4.395 | -2.4 | 11.29 |
| (IV) market division | 37 | 7.875 | 5.437 | -3.105 | 15.222 |
| - *Unilateral cover bidding* | 19 | 8.556 | 6.223 | -2.756 | 15.054 |
| - *Cross-cover bidding* | 18 | 7.156 | 4.532 | -3.105 | 15.222 |

I. Without condition (q.iv)
(estimated with 475 non-collusive observations)

| | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| All | 102 | 7.804 | 4.155 | -1.774 | 15.745 |
| (I) price fixing | 31 | 6.854 | 3.747 | -.818 | 13.382 |
| (III) cover bidding | 32 | 6.971 | 4.074 | -.698 | 13.483 |
| - *Unilateral cover bidding* | 20 | 6.789 | 4.469 | -.698 | 13.483 |
| - *Cross-cover bidding* | 12 | 7.275 | 3.481 | .821 | 11.536 |
| (IV) market division | 38 | 9.313 | 4.254 | -1.774 | 15.745 |
| - *Unilateral cover bidding* | 20 | 10.247 | 4.557 | 1.293 | 15.745 |
| - *Cross-cover bidding* | 18 | 8.275 | 3.744 | -1.774 | 14.39 |

J. Qualified bidders only
(estimated with 342 non-collusive observations)

| | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| All | 102 | 8.113 | 4.774 | -4.421 | 16.464 |
| (I) price fixing | 31 | 7 | 5.304 | -4.421 | 16.464 |
| (III) cover bidding | 32 | 8.033 | 5.177 | -2.348 | 15.251 |
| - *Unilateral cover bidding* | 20 | 7.934 | 5.149 | -2.348 | 15.251 |
| - *Cross-cover bidding* | 12 | 8.199 | 5.45 | -.364 | 14.465 |
| (IV) market division | 38 | 9.094 | 3.861 | .653 | 15.161 |
| - *Unilateral cover bidding* | 20 | 9.73 | 4.293 | 1.679 | 15.161 |
| - *Cross-cover bidding* | 18 | 8.388 | 3.293 | .653 | 14.213 |

# 2. The Impact of Minimum Score Discrimination (MSD) Rule on Public Procurement

## 2.1 Introduction

Public procurement contracts in Korea are generally awarded through a reverse auction process. Bidders submit financial and technical proposals that correspond with the owner's project goal, and the bidder that offers the best value for money is awarded the contract. Each proposal is independently evaluated by members of the evaluation panel according to a specified scoring rule, and the results are aggregated into one overall score to determine the hierarchy of bidders.[56] Most theoretical studies on procurement auctions focus on independent scoring rules, under which a bidder's score is determined by its own price and quality. Yet, in practice, we often face interdependent scoring rules that assign a score based on attributes of other bids. One example is the Weighted Criteria algorithm, which is the most widely implemented selection method in Korea. Under this approach, weights are assigned to evaluation criteria according to their relative importance, and the overall score is calculated as the weighted aggregate of price and quality scores. The problem is that the price score is typically computed by normalizing the price bid against a reference point, generally the lowest price bid. This implies that, while the cheapest bidder receives full marks on the price side, the price score of other bidders is determined by how far away they are from the lowest price. Such interdependency in bid evaluation makes it difficult for a tenderer to make bidding decisions and to predict its final score and ranking.

There is a scoring rule unique to Korea's public procurement system that creates interdependency in the quality dimension as well. When a minimum score discrimination

[56] Before 2010, the evaluation panels were randomly selected from a pool of more than 3000 technical consultants on the day of the assessment. Today, the Public Procurement Service (PPS) selects a smaller pool of technical experts (serving for one or two years) that will be in charge of evaluating design proposals submitted for publicly procured projects. In 2020, 56 members are appointed to the design evaluation committee, 28 of whom are outside experts such as professors and public organization officers.

(hereafter, MSD) rule is adopted, quality scores of bidders other than the best designer are adjusted downward when their score difference is less than a predefined discrimination rate.[57] This implies that there cannot be a tie or a tight win in the quality dimension, and what matters is the ranks of quality scores and not the size of gaps between adjacent scores. While the highest-quality bidder receives a score that corresponds to the level of design it has accomplished, other bidders are assigned adjusted values depending on the definition and magnitude of the rule. There are four types of MSD rules observed in the evaluation process, the former two taking place at the individual evaluator level and the latter two taking place at the entire panel level. (We explore the differences between the four types in more detail in the subsequent section.) In the present study, we are interested in analyzing the effect of the fourth one, because it is most likely to distort bidders' participation decision and bidding decision.

MSD rules are generally implemented by a procuring entity to increase competition in design and to deter anticompetitive behavior such as price dumping.[58] When a bidder with an abnormally low bid is awarded a contract, it may lead to undesirable consequences such as the contractor performing poorly or being unable to complete the work for the offered price, while with a discriminatory scoring system, procuring entities can put greater emphasis on the technical aspect of a project. Yet, as the chance of winning a contract may depend heavily on whether or not one can produce the highest-quality design, it could discourage contractors from participating in such tenders and weaken price competition among bidders, thus leading to higher procurement prices. We should not forget that the goal of an owner is to achieve not only high quality but also cost effectiveness. This is especially true for public projects financed by public funds: procuring entities should strive for a competitive and transparent tender process with the aim of obtaining the best value for money. If the MSD rule has unintended consequences such as limiting bidder participation and increasing prices, procuring officials should be more careful in its application. In order to determine the effect of MSD on procurement,

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[57] We use "minimum score discrimination rule" to refer to "강제차등점수제", having found no official translation of the term.

[58] Price dumping is a predatory practice of deliberately bidding lower than the competitive price to win an auction.

we use a two-stage forecasting method to predict the counterfactual scenario where there is no discrimination. Specifically, in the first stage, we estimate the regression equation of number of bidders and winner's quality advantage [59] using non-MSD auctions; then, we predict the expected outcomes of the two variables if there were no discrimination for MSD auctions. In the second stage, we estimate the price equation using non-MSD auctions, and we substitute the estimates derived in the first stage for the actual values when predicting the counterfactual contract price for MSD auctions. The result suggests that the MSD rule leads to the government paying an additional price of 9.86% on average; meanwhile, it appears the winner's quality score has increased by less than a point on average (see Appendix 2.C and Appendix 2.D). Caution is warranted when comparing the two effects, but the direction and size of the estimates raises a question about the efficiency and effectiveness of the policy.

This paper proceeds as follows. The rest of this section describes the types of MSD rules and examines their effect using a simple model. Section 2 gives a brief literature review, and Section 3 describes data. Section 4 explains the model, and Section 5 presents the results. Section 6 concludes.

### *2.1.1. Types of MSD rules*

In a typical project, about 10-20 experts, who have sufficient expertise and experience in relevant fields, are selected to serve on the evaluation panel, with 2-4 members assigned for each section. They independently score each technical proposal using pre-defined evaluation criteria and weights. The points awarded by each evaluator are averaged to obtain the mean section score, which are then added across sections to determine the final quality score.

Procuring entities use various combinations of MSD rules to differentiate between technical proposals. There are four types of MSD rules observed in the evaluation process. The first two are implemented at the individual evaluator level; they ensure that there is a

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[59] We coin the term quality advantage to describe the difference between the winner's quality score and the average quality score of losers, divided by the average quality score of losers.

sufficient distance (1) between subscores of each evaluation subfactor and (2) between total scores summed across the subfactors for each evaluator. When these scores are averaged across panel members to obtain the mean section score, the third type of MSD rule is applied, increasing the distance (3) between average scores in each section. Finally, these scores are summed across the sections to obtain the final quality score. The fourth type of MSD rule is applied at this point to increase the distance (4) between final quality scores of bidders.

Below table shows an example of a tender evaluation. Consider a procurement auction that adopts the rule of Weighted Criteria. Suppose three contractors—Bidder A, Bidder B, and Bidder C—enter the auction and submit financial and technical proposals. There are four panel members, two assigned for construction section and two assigned for operation section. Panel A of Table 1 displays the evaluation grid of Evaluator 1, who is assigned to grade the construction part. Each proposal is evaluated on four subfactors, with point allocation as specified. Type 1 MSD rule ensures that in each subfactor, there is a 10% difference between adjacent subscores (i.e., if a total of 20 points is possible, there should be a 2-point gap between bidders). This is equivalent to assigning numerical values based on a qualitative rating scale. These subscores are summed across the subfactors to yield a total score for each proposal. Note that there is only a 0.5-point difference in total scores between Bidders A and B. Yet, when Type 2 MSD rule is applied, the score difference is adjusted to 5 points (i.e., 10% of 50 points), resulting in Bidders B and C receiving adjusted scores of 46.5 and 41.5, respectively.

Panels B1 and B2 of Table 1 show the combined results of the evaluation panel. Let us first look at Panel B1. For each proposal, the total scores assigned by Evaluators 1 and 2 are averaged to obtain the mean score in the construction section, and the scores assigned by Evaluators 3 and 4 are averaged to obtain the mean score in the operation section. These section scores are totaled to obtain the final quality score. Before discrimination, the final score of Bidders A, B, and C is 90.5, 88, and 78, respectively. When Type 3 MSD rule is applied, the section score of non-highest alternatives (i.e., Bidders A and C in the construction section and Bidders B and C in the operation section) is adjusted downward by 5 points (i.e., 10% of 50 points), thereby adjusting the final score of Bidders A, B, and C to 88, 88, and 73, respectively. Now suppose Type 4 MSD rule is adopted instead of Type 3. In Panel B2, the final quality scores of non-best designers are adjusted downward by 10 points (i.e., 10% of 100 points), resulting in Bidders B and C receiving the adjusted final score of 80.5 and 70.5, respectively. In all of the cases, Bidder A receives the highest rating and is ranked first, however, the score advantage Bidder A enjoys from being the best designer differs across the schemes. The severity of discrimination is the greatest under Type 4 MSD rule, which ensures at least a 10-point difference between adjacent scores regardless of how close they are pre-discrimination.

Table 1. Four types of MSD rules

Panel A. Evaluator 1's evaluation result

| Section: Construction | Total | Bidder A | Bidder B | Bidder C |
|---|---|---|---|---|
| MSD **(1)** between subscores (10%): | | | | |
| a. Constructability | 20 | 18 | 20 | 16 |
| b. Planning | 15 | 15 | 12 | 13.5 |
| c. Maintenance | 10 | 9 | 10 | 8 |
| d. Safety | 5 | 4.5 | 4 | 5 |
| Total quality score | 50 | 46.5 | 46 | 42.5 |
| MSD **(2)** between total scores (10%) | 50 | 46.5 | 41.5 | 36.5 |

*Note.* Each criterion is assessed such that there is a 10% difference between subscores in that criterion (Type 1). A total score is a sum of subscores across criteria. Total scores of non-best designers are adjusted downward by 10% under Type 2 MSD rule.

Panel B1. Aggregate evaluation result

| | Total | Bidder A | Bidder B | Bidder C |
|---|---|---|---|---|
| Section: Construction | | | | |
| Evaluator 1 total score | 50 | 46.5 | 41.5 | 36.5 |
| Evaluator 2 total score | 50 | 38 | 48 | 43 |
| Mean section score | 50 | 42.25 | 44.75 | 39.75 |
| MSD **(3)** between section scores (10%) | 50 | 39.75 | 44.75 | 34.75 |
| Section: Operation | | | | |
| Evaluator 3 total score | 50 | 47.5 | 42.5 | 37.5 |
| Evaluator 4 total score | 50 | 49 | 44 | 39 |
| Mean section score | 50 | 48.25 | 43.25 | 38.25 |
| MSD **(3)** between section scores (10%) | 50 | 48.25 | 43.25 | 38.25 |
| Final quality score | 100 | 88 | 88 | 73 |

*Note.* A mean section score is calculated as the average of individual quality scores.

Section scores of non-best designers are adjusted downward by 10% under Type 3 MSD rule.

Panel B2. Aggregate evaluation result

| | Total | Bidder A | Bidder B | Bidder C |
|---|---|---|---|---|
| Construction average score | 50 | 42.25 | 44.75 | 39.75 |
| Operation average score | 50 | 48.25 | 43.25 | 38.25 |
| Final quality score | 100 | 90.5 | 88 | 78 |
| **(4)** MSD between final scores (10%) | 100 | 90.5 | 80.5 | 70.5 |

*Note.* A final quality score is the sum of section scores. Final scores of non-best designers are adjusted downward by 10% under Type 4 MSD rule.

Under Weighted Criteria, the overall score is calculated by multiplying price and quality scores by their respective percentage weight. It uses a formula such as $TS = w^p p^s + w^q q$, where $w^p$ and $w^q$ are weights that add up to one and $p^s$ is price score that is decreasing in price, like $p^s = (p_{min}/p) * 100$. The assigned weights represent the tradeoff between cost and quality—the relative importance of high quality versus low price to the owner.[60] Note that a low score on one criterion can be compensated by a high score on another. Given such scoring system, we can imagine a bidder with a relatively low technical capacity to quote a low price (closer to its cost) in order to counteract its weakness in design, while a strong bidder has more flexibility in choosing price. Previous studies have shown that a weak bidder tends to bid more aggressively than a strong bidder in an asymmetric first-price auction (De Silva et al., 2003; Li, 2012; Maskin and Riley, 2000). That being said, when a discriminatory evaluation system is in place, especially Type 4 MSD rule, it is difficult to compensate low quality with low price. In the above example, if the weights between quality and price are in a proportion of 60:40, Bidder A enjoys a score advantage of 6 points against Bidder B (12 points against Bidder C). Unless Bidders

[60] For design-build projects, contracting authorities tend to put more emphasis on the technical aspect than the financial aspect of a project.

T1. Quality weight under Weighted Criteria

| Quality weight | All | < 50% | 50% | 50-60% | 60% | 60-70% | 70% | > 70% |
|---|---|---|---|---|---|---|---|---|
| N | 732 | 51 | 75 | 83 | 227 | 44 | 218 | 34 |
| Percent | 100 | 6.97 | 10.25 | 11.34 | 31.01 | 6.01 | 29.78 | 4.64 |

B and C submit a significantly low price, it is almost impossible to overcome their disadvantage in the quality dimension. It may be in the owner's interest to favor high quality bidders in order to achieve superior design quality. However, if the auction environment is constructed such that the best designer enjoys an indisputable score advantage, bidders would have lower incentive to participate and to compete in terms of price, leading to higher contract prices and a waste of taxpayer money.

Thus far, we have assumed a 10% discrimination rate for all types of MSD rules. In practice, the provisions of the policy vary across institutions, and the contracting authority has discretion to determine what rule to be applied at what rate, which can be as high as 15%. The Ministry of Land, Infrastructure and Transport (MOLIT) specifies that a rate should be chosen within 15% (Article 37 of MOLIT Directive No. 1331), and the Public Procurement Service (PPS) recommends using a rate between 3-10% (Article 30 of PPS Directive No. 1928). Panel A of Table 2 describes various methods, suggested by the MOLIT and the PPS, of applying MSD rules for the evaluation of technical proposals in a multi-criteria procurement auction. Note that different combinations of MSD rules have been applied over time, and Type 4 MSD rule has become more accepted in recent years. Panel B of Table 2 shows the MOLIT's recommended policy for auctions under Weighted Criteria, and Type 4 MSD rule is adopted in auctions with quality weight over 60%. It is unclear how the discrimination rates, 7% and 10%, are selected for each range of quality weight, but the severity of discrimination seems to increase with the weight in order to enhance quality competition among bidders.[61]

Table 2. Provisions of MSD rule

Panel A. Trends in application of MSD rule

| Date amended | MOLIT | Date amended | PPS |
|---|---|---|---|
| 2008. 3. 31 | - Type 1<br>- Type 1 and Type 4 | 2008. 7. 25 | - Type 1<br>- Type 1 and Type 4 |

[61] Some agencies apply different discrimination rates depending on the number of bidders. For example, the Korea Land and Housing Corporation (LH) applies Type 3 MSD rule at a rate of 15% for two bidders, 10% for three bidders, 7% for four bidders, and 5% when there are more than five bidders.

| | | | |
|---|---|---|---|
| | (3-5%) | | (3-5%) |
| 2010. 1. 1 | - Type 1<br>- Type 1 and Type 3 (5-15%) | 2010. 5. 14 | - Type 1 (5-15%)<br>- Type 1 and Type 3 (5-15%) |
| 2012. 7. 5 | - Type 1<br>- Type 1 and Type 3 (-15%)<br>- Type 1 and Type 4 (-15%) | 2011. 10. 15 | - Type 1 (5-10%)<br>- Type 1 and Type 2 (5-10%) |
| 2014. 5. 23 | - Apply at least two:<br>(a) Type 1(-15%)<br>(b) Type 3 (-15%)<br>(c) Type 4 (-15%) | 2018. 8. 1 | - Type 1 (5-10%)<br>- Type 1 and Type 2 (5-10%)<br>- Type 1 and Type 4 (5-10%)<br>- Type 1, Type 2, and Type 4 (5-10%) |

*Note*. The left-hand panel shows methods of applying MSD suggested by the MOLIT (Operational Regulations on Construction Technology Development and Management), and the right-hand panel displays evaluation standards set by the PPS (Regulations for Establishment and Operation of Technical Advisory Committee).

Panel B. MOLIT guideline for application of MSD rule

| | MSD rule |
|---|---|
| October 2012 - March 2016: | |
| - quality weight less than 70% | Type 1 (10%) and Type 3 (10%) |
| - quality weight over 70% | Type 1 (10%) and Type 4 (7%) |
| March 2016 - Today: | |
| - quality weight less than 60% | Type 1 (10%) and Type 2 (10%) |
| - quality weight between 60-70% | Type 1 (10%), Type 2 (10%), and Type 4 (7%) |
| - quality weight over 70% | Type 1 (10%) Type 2 (10%), and Type 4 (10%) |

*Note*. This table shows the MSD rule recommended by the MOLIT depending on the weight assigned for technical criteria.

### *2.1.2. Iso-score curve under Type 4 MSD rule*

In this section, we use a simple model to analyze bidding behavior under Type 4 MSD rule. Suppose bidder $i$ submits a multi-attribute sealed bid $(p_i, q_i)$. When the auction is subject to the MSD rule, bidder $i$'s quality score $q_i$ is adjusted downward if (1) bidder $i$ is not the highest-quality bidder and (2) the difference from the next higher ranked quality score is less than some predefined threshold value. One scoring formula of Weighted Criteria that implements MSD is follows:

$$S(p,q) = \begin{cases} \gamma_1\left({}^{p_{min}}/_{p} * 100\right) + \gamma_2 q & \text{if } q = q_{max} \\ \gamma_1\left({}^{p_{min}}/_{p} * 100\right) + \gamma_2(\hat{q} - \delta) & \text{if } q \neq q_{max}, \hat{q} \in (q, q+\delta) \\ \gamma_1\left({}^{p_{min}}/_{p} * 100\right) + \gamma_2 q & \text{if } q \neq q_{max}, \hat{q} \in (q+\delta, \infty) \end{cases} \qquad (2.a)$$

where $p_{min}$ is the lowest price bid submitted, $q_{max}$ is the highest quality bid submitted, $\hat{q}$ is the next higher ranked quality score to $q$, and $\delta > 0$ is the exogenously determined rate of discrimination (i.e., threshold value). The first and third piece of the function is equivalent to the one generated by Weighted Criteria with no discrimination. The second piece is where the distortion arises in bid evaluation. Note that, in practice, there are different ways of introducing discrimination in the quality dimension. Here, we assume that $\delta$ is the minimum raw score difference between adjacent scores, but in some cases, the rule is applied such that $\delta$ is their percentage difference, that is, the adjusted quality score is $q = \hat{q}(1 - \delta/100)$. In some cases, the winner's quality score is scaled to 100 and losers' scores are adjusted from thereafter (i.e.,$100 - \delta, 100 - 2\delta, \cdots$).

Consider an auction that implements the scoring rule specified in $(2.a)$. Without loss of generality, suppose Bidder A is the winner. For another bidder, say Bidder B, to score the same level as Bidder A, the iso-score function should satisfy the following:

$$\begin{cases} \gamma_p\left(\frac{p^B}{p^A}\right) + \gamma_q q^A = \gamma_p(1) + \gamma_q q^B & \text{if } p^A > p^B, q^A \in (q^B + \delta, \infty) \qquad (3.a) \\ \gamma_p(1) + \gamma_q q^A = \gamma_p\left(\frac{p^A}{p^B}\right) + \gamma_q q^B & \text{if } p^A < p^B, q^B \in (q^A + \delta, \infty) \qquad (3.b) \end{cases}$$

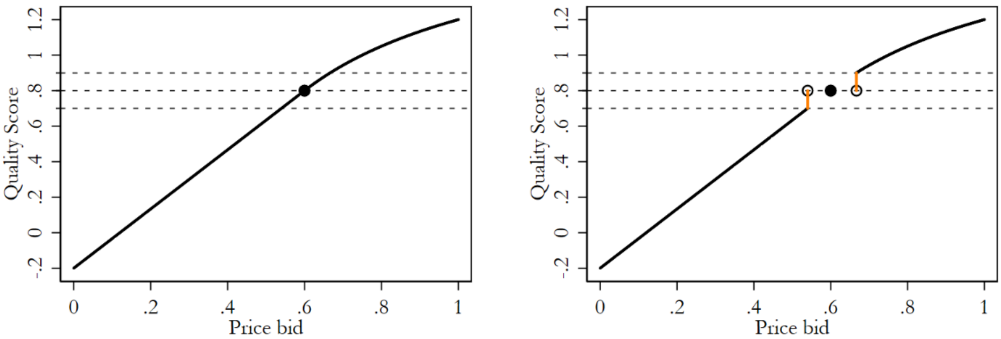
$$\begin{cases} \gamma_p\left(\frac{p^B}{p^A}\right) + \gamma_q q^A = \gamma_p(1) + \gamma_q(q^A - \delta) & \text{if } p^A > p^B, q^A \in (q^B, q^B + \delta) \qquad (3.c) \\ \gamma_p(1) + \gamma_q(q^B - \delta) = \gamma_p\left(\frac{p^A}{p^B}\right) + \gamma_q q^B & \text{if } p^A < p^B, q^B \in (q^A, q^A + \delta) \qquad (3.d) \end{cases}$$

Note that the functional pieces depend on whether or not one submits the higher price and whether the quality score gap is greater than the threshold value, $\delta$. An example iso-score curve is illustrated in Figure 1 (Kang, 2019; Bergman et al., 2017). In panel (a), when no discrimination is place, there is a smooth iso-score curve, and any combination of price and quality that lies above the curve can achieve a higher overall score than Bidder A. If we suppose that Bidder B's design is of similar but slightly inferior quality level as Bidder A's, Bidder B only needs to reduce its price bid slightly to obtain the higher score. Meanwhile, in panel (b), when there is quality score discrimination of $\delta$%, the iso-score curve has a kink at $(q_A - \delta)$ and $(q_A + \delta)$, and Bidder B has to cut its price beyond this level in order to counteract its score disadvantage in the quality dimension. Note that the marginal benefit (loss) of bidding slightly lower (higher) is zero within this range. The greater is the discrimination rate $\delta$, the greater is the disincentive to compete in price, which can lead to an increase in procurement cost. In the next sections, we will show empirically that the price paid by the government under MSD is substantially greater than the one under no discrimination.

Figure 1. Iso-score curve

(a) Weighted Criteria with no discrimination

(b) Weighted Criteria with Type 4 MSD rule




*Note.* The horizonal axis is the price bid, and the vertical axis is the quality score. Price and quality score are normalized to $(0,1)$. The figure displays the iso-score curve when Bidder A's bid is $(p_A, q_A) = (0.60, 0.80)$, $\gamma_p = \gamma_q = 0.5$, and $\delta = 0.10$. Suppose $q_B = 0.79$. For Bidder B to score higher than Bidder A, it has to cut its price below $0.594$ in Panel (a) and $0.54$ in Panel (b) to make up for the quality disadvantage. Now suppose $q_B = 0.81$. Bidder B can score higher than Bidder A even if it raises price to $0.667$ in Panel (b).

## 2.2 Literature Review

To the best of our knowledge, no other country uses the MSD rule to differentiate between technical proposals, and no previous study has examined the effect of MSD on the tender process. There are scoring rules that bear resemblance to the MSD method such as adjectival and color ratings (i.e., qualitative rating), but these methods are only employed in the assessment of subfactors as with Type 1 MSD rule. Molenaar and Tran (2015) provide examples of adjectival scales used by the Department of Transportation of California (Caltrans), Minnesota (MnDOT) and New York (NYSDOT), but in all of the cases, qualitative rating is used to differentiate between proposals within a technical subfactor. Despite careful research, we could not find any award algorithm that skews the final quality scores of bidders as Type 4 MSD rule does. In other contexts, rating schemes similar to Type 4 MSD rule are often used to distinguish between performance levels. One example is the academic grading system, which uses grade letters such as A, B, C, D, and F to determine differences in student achievement. Another example is the ranking system for sports players, assigning distinct point scores to winning (or placing in) different levels of game events. Yet, these examples have minor relevance to the present study, as we are interested in analyzing the multi-dimensional effect of a discriminatory scoring system, that is, the significance of discrimination on one side of evaluation (i.e., quality) to a bidder's decision on another side (i.e., price).

When quality is ranked through adjectival rating, each evaluation subfactor is assessed using adjectival descriptions such as excellent, good, poor, and unacceptable to indicate whether the proposal has met the technical requirements (Scott et al., 2006).[62] These descriptions may be assigned a number (or a range of numbers) to determine a point score for that criterion. Such composite method allocates numerical scores according to the predefined point spread of adjectival ratings, producing the same effect as adjusting scores by a fixed discrimination rate according to the hierarchy of numerical ratings. For example, giving a score ranging from 0 (poor) to 20 (excellent) with increments of 2 is

[62] A color code system is a similar method where color descriptors are used in place of adjectival descriptors. For example, colors blue, green, yellow, and red may be associated with excellent, good, satisfactory, and unsatisfactory, respectively.

equivalent to Type 1 MSD rule implemented in Table 1 for the subfactor 'Constructability'. One drawback of adjectival rating is that there can be a considerable gap between the high and low ends of each grade if broad grade categories are used (Byrns, 1992). Also, those that fall on the borderline between two grades can have similar merits and characteristics but be assigned different ratings. These analyses are applicable to the case of the MSD rule, in which the problem may be more serious because discrimination often occurs in multiple levels.

We are uncertain where the MSD rule originates from, how it has been transformed into its current form, and why it is still in place despite negative reactions. The earliest document that mentions MSD is a 1996 report by the MOCT (currently MOLIT), which expresses concerns at the time that the rule is based on unclear grounds and should be abolished.[63] There are news reports of complaints made by medium-sized firms that the MSD rule gives preferential treatment to large firms. Even so, procuring entities have increasingly adopted discriminatory scoring methods in the evaluation of technical proposals as described in Table 2. Some of the rationales mentioned by government officials for using MSD are to increase competition in quality and to deter undesirable pricing behavior such as price dumping, but these goals can be achieved without artificially distorting the scoring algorithm, such as by increasing the quality weight (see Appendix 2.C for more information). One potentially unique advantage of the MSD rule is that as it allows more differentiation between proposals, it could reduce the

[63] The report is based on interviews of experts that are directly or indirectly related to the construction industry. The table below indicates that 48% of them would like to have the MSD rule abolished while 29.6% would like to maintain the current state. The report also notes that the standard discrimination rate used for DB auctions at the time is 10%.

T2. Response on MSD scoring method (KICT, 1996)

| (Unit: Percentage) | Mean | Central evaluation panel | Local evaluation panel | Construction firm | Engineering firm | Procuring entity |
|---|---|---|---|---|---|---|
| Abolish the rule | 48 | 43.9 | 50 | 57.1 | 56.5 | 32.4 |
| Lower the rate | 14 | 13.6 | 14.3 | 5 | 13 | 24.4 |
| Raise the rate | 5.7 | 3.2 | 0 | 14.3 | 0 | 10.8 |
| Keep the current state | 29.6 | 34.8 | 35.7 | 23.3 | 21.7 | 32.4 |
| Others | 2.7 | 4.5 | 0 | 0 | 8.8 | 0 |

risk of bid protests and litigation by unsuccessful bidders, but further research is necessary to confirm this theory.

Despite the wide usage of the MSD rule in both public and private procurement in Korea, it has been largely neglected and unexplored in the literature. There are a few articles that describe the logic and procedure of the rule, but we could not find any research that examine the role and impact of a discriminatory scoring system in the procurement process, either theoretically or empirically. That being said, the present study is the first attempt to investigate the consequences of the MSD rule: we focus on the effect of the rule on procurement cost in the main analysis and examine its implications on the quality side in the Appendix.

## 2.3 Data

We use the same set of data presented in Chapter 1. See Section 1.3 for more information. For simplicity of analysis, we restrict the sample to projects that adopt Weighted Criteria and exclude cases investigated by the KFTC for collusion. The final dataset contains information on 639 projects procured between 2007-2020. Since the application of Type 4 MSD rule is not specified in our data, we proxy it by the integerness of the minimum (absolute or percentage) difference between quality scores. We compare the records provided by the Construction Association of Korea (CAK) and the Public Procurement Service (PPS) in case one reports ratings post-adjustment and the other does not. We find that about a fourth of our sample includes a quality score difference that is a whole number between 5%-15%.[64] Yet, this method alone has some limitations. It is possible that these projects implement other types of MSD rules, as there can be a unanimous preference for one proposal over others across sections. For instance, if Type 1-3 MSD rule is in place and all panel members assign the highest rank to one bidder, there would be an integer score difference between the best designer and other bidders. Another problem is that we cannot distinguish between a project that does not implement MSD and the one that does

[64] There are cases where the quality score difference is a whole number less than 5 or greater than 15, but we conclude that these cases do not adopt Type 4 MSD rule.

but the rule is not binding. For example, if the rule discriminates quality by 5% but the raw score difference is greater than 5, this case would be sorted as not adopting the rule as per our method of classification. Yet, we assume that the effect of MSD in these cases is minimal because the rule would influence bidders' entry and bidding decisions only when it is sufficiently discriminatory.

Going forward, we will refer to Type 4 MSD rule simply as "MSD" or "discrimination rule". In order to verify the existence of the MSD rule, we examine information published on government websites and third-party sources such as news articles. Most information available today are on auctions procured after 2011 when the MOLIT announced to increase transparency and public access to administrative information.[65] We found detailed results of design evaluation (such as the rating sheet and its narrative justification) on various projects, many of which are procured by affiliated institutions of the MOLIT such as the Korea Rail Network Authority (KR) and the Korea Expressway Corporation (KEC). Not much information was available on projects procured by local governments and public organizations. After reviewing the source materials manually, we confirm that a total of 101 cases in which the quality score difference is a whole number does in fact implement the discrimination rule.[66] For 73 of these cases, we found data on quality scores before the application of the MSD rule. There are 85 remaining cases that are suspicious but uncertain as to which type of discrimination rule is in effect. Table 3 reports the frequency of discrimination rates for the confirmed and unconfirmed samples. Note that in most cases of the confirmed sample, a rate of 7% or 10% is used, consistent with the MOLIT's evaluation guideline (see Panel B of Table 2).[67]

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[65] It was announced in October 2011 that the results of design evaluation of DB auctions conducted by the MOLIT would be fully disclosed on its website, however, not all information are publicly available today (http://www.molit.go.kr/USR/NEWS/m_71/dtl.jsp?id=95069035).

[66] We find that 15 cases in which the quality score difference is a whole number actually implement Type 2 or Type 3 MSD rule.

[67] Procuring entities such as Korea Rail Network Authority (KR) and Korea Expressway Corporation (KEC) typically use a discrimination rate of 7% or 10%.

Table 3. Frequency of integer quality score differences

(a) Discrimination rates in confirmed sample

| Value | Freq. | Percent |
|---|---|---|
| 5 | 3 | 2.97 |
| 7 | 50 | 49.50 |
| 8 | 4 | 3.96 |
| 8.5 | 1 | 0.99 |
| 10 | 40 | 39.60 |
| 15 | 3 | 2.97 |
| Total | 101 | 100.00 |

(b) Integer differences in unconfirmed sample

| Value | Freq. | Percent |
|---|---|---|
| 3 | 1 | 1.18 |
| 5 | 29 | 34.12 |
| 7 | 16 | 18.82 |
| 10 | 29 | 34.12 |
| 15 | 10 | 11.76 |
| Total | 85 | 100.00 |

*Note.* The table excludes cases of collusive tendering. In (a), there is one case of MSD in which the discrimination rate is not an integer, but this seems to be a unique and uncommon case. In (b), we include one case in which the quality score difference is 3; we found news articles stating that the MSD rule is used in that case, but it is uncertain which of the four rules is applied.

Table 4 shows the frequency distribution of construction category, project size (classified into seven grades), procurement year, delivery method, and site location under MSD and under nondiscrimination. There are differences in the composition of the samples due to limitations in data collection. The confirmed sample is comprised of projects mostly in the field of civil engineering (especially transportation engineering such as roads, railways, ports, and harbors) and in Grade 1 (ranging from 111.64 billion KRW to 592.14 billion KRW). We have limited information on the application of MSD in other types of construction work. If we include the 84 unconfirmed cases, the MSD sample is quite similar in composition to the non-MSD sample.

Table 4. Frequency table for categorical data

| | Non-MSD | | MSD | | | |
|---|---|---|---|---|---|---|
| | | | Confirmed cases | | Unconfirmed cases | |
| | Freq. | Percent | Freq. | Percent | Freq. | Percent |
| Total | 453 | 100.00 | 101 | 100.00 | 85 | 100.00 |
| Construction category | | | | | | |
| (i) civil engineering: | | | | | | |
| (i.1) transport infrastructure | 86 | 18.98 | 49 | 48.51 | 14 | 16.47 |
| (i.2) waterworks | 59 | 13.02 | 20 | 19.80 | 13 | 15.29 |
| (i.3) other civil engineering | 20 | 4.42 | 3 | 2.97 | 1 | 1.18 |
| (ii) architecture | | | | | | |
| (ii.4) non-residential | 179 | 39.51 | 16 | 15.84 | 37 | 43.53 |
| (ii.5) residential | 30 | 6.62 | 4 | 3.96 | 4 | 4.71 |
| (iii) industrial equipment | | | | | | |
| (iii.6) industrial equipment | 79 | 17.44 | 9 | 8.91 | 16 | 18.82 |
| Project size | | | | | | |
| Grade 1 | 150 | 33.11 | 66 | 65.35 | 14 | 16.47 |
| Grade 2 | 90 | 19.87 | 20 | 19.80 | 15 | 17.65 |
| Grade 3 | 84 | 18.54 | 9 | 8.91 | 19 | 22.35 |
| Grade 4, 5, 6, 7 | 129 | 28.48 | 6 | 5.94 | 37 | 43.53 |
| Year | | | | | | |
| 2007 | 22 | 4.86 | 1 | 0.99 | 5 | 5.88 |
| 2008 | 48 | 10.60 | 1 | 0.99 | 16 | 18.82 |
| 2009 | 105 | 23.18 | | | 14 | 16.47 |
| 2010 | 65 | 14.35 | 1 | 0.99 | 6 | 7.06 |
| 2011 | 55 | 12.14 | 2 | 1.98 | 14 | 16.47 |
| 2012 | 46 | 10.15 | 2 | 1.98 | 9 | 10.59 |
| 2013 | 44 | 9.71 | 10 | 9.90 | 14 | 16.47 |
| 2014 | 15 | 3.31 | 9 | 8.91 | 3 | 3.53 |
| 2015 | 18 | 3.97 | 13 | 12.87 | 1 | 1.18 |
| 2016 | 16 | 3.53 | 19 | 18.81 | 1 | 1.18 |
| 2017 | 7 | 1.55 | 20 | 19.80 | | |
| 2018 | 6 | 1.32 | 13 | 12.87 | 1 | 1.18 |
| 2019 | 5 | 1.10 | 4 | 3.96 | | |
| 2020 | 1 | 0.22 | 6 | 5.94 | 1 | 1.18 |
| Delivery method | | | | | | |
| - Technical proposal | 76 | 16.78 | 27 | 26.73 | 7 | 8.24 |
| - Alternative bid | 42 | 9.27 | 7 | 6.93 | 5 | 5.88 |
| - Design-Build | 335 | 73.95 | 67 | 66.34 | 73 | 85.88 |
| Site location | | | | | | |
| Greater Seoul Metropolitan | 179 | 39.51 | 37 | 36.63 | 33 | 38.82 |
| Other Metropolitan | 96 | 21.19 | 13 | 12.87 | 16 | 18.82 |
| Local region | 178 | 39.29 | 51 | 50.50 | 36 | 42.35 |

*Note.* The rightmost column includes the 85 cases that are suspicious but uncertain as to whether they adopt Type 4 MSD rule. Construction work may be classified into 11 subcategories: (i.1.1) railway and subway, (i.1.2) other transportation, (i.2.3) harbor, (i.2.4) riverworks and agricultural engineering, (i.2.5) other waterworks, (i.3.6) other civil engineering, (ii.4.7) exhibition, assembly, and sports facility, (ii.4.8) other non-residential, (ii.5.9) residential, (iii.6.10) wastewater, and (iii.6.11) other industrial equipment. As for project size, Grade 1 is the highest category associated with estimated price over 150 billion KRW in (i) civil engineering and over 110 billion KRW in (ii) architecture and (iii) industrial equipment; Grade 4 and under are associated with project size less than 50 billion KRW.

Summary statistics are reported in Table 5. One important observation is that the number of bidders is smaller under MSD than under nondiscrimination. The difference is statistically significant at the 5% (confirmed sample) and 1% (unconfirmed sample) levels, consistent with our hypothesis that the discriminatory scoring system can discourage bidder participation. Another observation is that the winner's quality advantage, which is defined as $\left(q^W - \overline{q^{/W}}\right)/\overline{q^{/W}}$, where $q^W$ is the winner's quality score and $\overline{q^{/W}}$ is the average quality score of bidders excluding the winner, is significantly higher under MSD than under nondiscrimination. This is consistent with our intuition that the MSD rule produces a greater spread of quality scores regardless of who participates in the auction. The table also presents statistics for variables related to the qualified contractor pool, introduced in the previous chapter (see section 1.3.5 for more information).[68] Note that the

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[68] We create a pool of contractors that are interested and qualified to participate in a particular auction. The standard we use is similar to those actually used by procuring entities during the prequalification phase. Two factors are evaluated: a contractor's (1) experience and performance on projects of similar nature and complexity and its (2) execution capacity in the construction field of a given project. We have information on 90 contractors that may be eligible to participate in a multi-attribute procurement auction (there are 63 distinct winners and 102 distinct bidders in the 492 observations). We argue that a contractor that satisfies the following conditions is qualified to undertake a project:

(q.i) It has completed at least one project successfully (as a sole contractor or as a consortium leader) in the same construction subcategory as a given project.

(q.ii) Its total performance record over the last five years (preceding the current year) in the same construction category as a given project is greater than the estimated price of a given project.

(q.iii) Its grade level is associated with a range of values equal or greater than the estimated price of a given project.

(q.iv) It is a top contractor when (a) the winner is a top contractor and (b) the proportion of top contractors in a qualified contractor pool exceeds the threshold value. It is a non-top number of qualified contractors under confirmed MSD is smaller on average than under nondiscrimination or unconfirmed MSD. We also observe that the winner's execution capacity relative to qualified contractors, which measures its general technical superiority, is substantially smaller on average under confirmed MSD than under nondiscrimination or unconfirmed MSD. The differences in statistics could be due to the measurement error in the unconfirmed MSD sample, which may include cases of nondiscrimination or those that adopt MSD rules other than Type 4. For this reason, from here on, we focus our analysis only on the confirmed cases of MSD.

Table 5. Descriptive statistics

| Variable | Type | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|---|
| Estimated price (1 billion KRW) | Non-MSD | 453 | 112.774 | 85.472 | 5.264 | 584.298 |
| | Confirmed | 101 | 178.398 | 95.742 | 22.346 | 592.14 |
| | Unconfirmed | 85 | 79.849 | 62.382 | 15.06 | 270.469 |
| Number of bidders | Non-MSD | 453 | 2.592 | .882 | 2 | 8 |
| | Confirmed | 101 | 2.416 | .588 | 2 | 4 |
| | Unconfirmed | 85 | 2.259 | .58 | 2 | 5 |
| Winner quality advantage | Non-MSD | 453 | 6.591 | 6.542 | -15 | 41.63 |
| | Confirmed | 101 | 12.839 | 5.658 | -16.368 | 25 |
| | Unconfirmed | 85 | 10.055 | 5.883 | -17.487 | 28.49 |
| Winner backlog ratio | Non-MSD | 451 | .607 | .207 | .003 | 1 |
| | Confirmed | 99 | .658 | .215 | .127 | 1 |
| | Unconfirmed | 85 | .625 | .216 | .095 | .995 |
| Winner execution capacity relative to losers ($REC^B$) | Non-MSD | 452 | .246 | 1.023 | -3.463 | 4.419 |
| | Confirmed | 101 | .133 | 1.149 | -2.758 | 2.782 |
| | Unconfirmed | 84 | .508 | 1.201 | -2.161 | 4.157 |
| Number of joint bidders | Non-MSD | 428 | 4.322 | 1.707 | 1 | 10 |
| | Confirmed | 95 | 5.979 | 2.278 | 1 | 10 |
| | Unconfirmed | 80 | 4.237 | 1.837 | 1 | 10 |
| Leader's stake (%) | Non-MSD | 428 | 49.223 | 14.223 | 28 | 100 |
| | Confirmed | 95 | 47.078 | 9.767 | 27 | 100 |
| | Unconfirmed | 80 | 49.894 | 16.098 | 28.5 | 100 |

*Variables related to qualified contractor pool:*

contractor when (a) the winner is not a top contractor and (b) the ratio of top contractors in qualified contractor pool is less than the threshold value. Otherwise, both types of contractors are allowed in the pool.

| | | | | | | |
|---|---|---|---|---|---|---|
| Number of qualified contractors | Non-MSD | 453 | 24.351 | 13.023 | 5 | 59 |
| | Confirmed | 101 | 19.059 | 11.399 | 7 | 51 |
| | Unconfirmed | 85 | 25.647 | 14.334 | 7 | 59 |
| Average backlog ratio of qualified contractors | Non-MSD | 453 | .616 | .088 | .362 | .826 |
| | Confirmed | 101 | .667 | .13 | .388 | .86 |
| | Unconfirmed | 85 | .615 | .086 | .4 | .781 |
| Winner execution capacity relative to qualified contractors ($REC^{QC}$) | Non-MSD | 453 | .527 | .951 | -3.185 | 2.809 |
| | Confirmed | 101 | .242 | .819 | -1.931 | 2.213 |
| | Unconfirmed | 85 | .576 | .955 | -3.165 | 2.314 |

*Note.* Winner backlog ratio is the ratio of the winner's current backlog over its maximum amount during the sample period. Winner price ratio is the ratio of successful contract price to estimated price in percentage terms. Winner quality advantage is the winner's quality score minus the average quality score of losers, divided by the average quality score of losers. Execution capacity between winner and losers ($REC^{B}$) is defined by $\ln(EC^{W}) - \overline{\ln(EC^{/W})}$, where $\ln(EC^{W})$ is the log execution capacity of winner and $\overline{\ln(EC^{/W})}$ is the average of the log execution capacity of losers. Execution capacity between winner and qualified contractors ($REC^{QC}$) is defined by $\ln(EC^{W}) - \overline{\ln(EC^{QC/W})}$, where $\ln(EC^{W})$ is the log execution capacity of winner and $\overline{\ln(EC^{QC/W})}$ is the average of the log execution capacity of qualified contractors excluding winner. Number of joint bidders refers to the number of members in a consortium, and leader's stake indicates the share of bid value held by the consortium leader.

In Panel A of Table 6, we analyze what kind of contractors enter the auction under MSD and under nondiscrimination. It displays the average weight on technical criteria and the difference in execution capacity between winner and losers ($REC^{B}$) for different size of projects. Under MSD, procuring entities seem to put greater emphasis on quality and bidders are slightly more homogenous in terms of technical capacity than under nondiscrimination. In small-scale projects, there appears to be more variation in bidder ability, but the sample size is too small to make comparisons between the groups. In Panel B, we report the winner's execution capacity relative to qualified contractors ($REC^{QC}$), broken down by the number of bidders. Note that $REC^{QC}$ is smaller under MSD than under nondiscrimination, especially when there are more than two bidders. This suggests that MSD is more commonly implemented in projects where similar contractors are expected to enter and intense quality competition is anticipated, but further research is needed to understand the nature of the contracting authorities' decision to adopt different types of MSD rules.

Table 6. Execution capacity between winner and losers

Panel A. Execution capacity between winner and losers by Grades

| Grade | Non-MSD | | | MSD (confirmed) | | |
|---|---|---|---|---|---|---|
| | N | Quality weight | $REC^B$ | N | Quality weight | $REC^B$ |
| Grade 1 | 150 | 61.685 | .117 | 66 | 67.468 | .091 |
| Grade 2 | 90 | 58.583 | .356 | 20 | 66 | .334 |
| Grade 3 | 84 | 61.89 | .201 | 9 | 66.667 | -.3 |
| Grade 4, 5, 6, 7 | 129 | 58.915 | .349 | 6 | 58.333 | .574 |

Panel B. Relative execution capacity by number of bidders

| Number of bidders | Non-MSD | | | MSD (confirmed) | | |
|---|---|---|---|---|---|---|
| | N | $REC^B$ | $REC^{QC}$ | N | $REC^B$ | $REC^{QC}$ |
| 2 | 270 | .29 | .512 | 64 | .277 | .353 |
| 3 or more | 182 | .181 | .549 | 37 | -.116 | .05 |

Table 7 shows the winner's price bidding and quality bidding behavior under confirmed MSD (Panel A) and under nondiscrimination (Panel B). The winner's price ratio [69] and quality score are broken down by the six winning scenarios possible: highest-quality/highest-price (HQ/HP), highest-quality/middle-price (HQ/MP), highest-quality/lowest-price (HQ/LP), middle-quality/middle-price (MQ/MP), middle-quality/lowest-price (MQ/LP), and lowest-quality/lowest-price (LQ/LP). Note that the winner is the HQ/HP bidder in more than half of all cases under MSD, and in all winning scenarios except for LQ/LP, the price ratio is higher under MSD than under nondiscrimination. This is consistent with our expectation that a discriminatory rating system weakens price competition and leads to higher prices. Note that in LQ/LP, although there is only one observation, the winner submits a significantly low price (63.1% of the estimated price) with a quality score of only 76.64. This suggests that even under MSD,

[69] A price ratio is defined as the ratio of successful contract price to estimated price, multiplied by 100%.

bidders can submit an abnormally low bid to win the auction, and if so, the adverse effects of price dumping can be more detrimental to procurement.

Table 7. Winner's bidding pattern in competitive auctions

Panel A. under MSD (confirmed)

Winner Price ratio (Frequency)

| Quality \ Price | Highest | Middle | Lowest | Total |
|---|---|---|---|---|
| Highest | 97.87 (47) | 96.92 (13) | 95.36 (40) | 96.74 (100) |
| Lowest | | | 63.01 (1) | 63.01 (1) |
| Total | 97.87 (47) | 96.92 (13) | 94.57 (41) | 96.41 (101) |

Winner quality score (Relative frequency)

| Quality \ Price | Highest | Middle | Lowest | Total |
|---|---|---|---|---|
| Highest | 91.27 (46.5%) | 88.44 (12.9%) | 90.29 (39.6%) | 90.51 (99.0%) |
| Lowest | | | 76.64 (1.0%) | 76.64 (1.0%) |
| Total | 91.27 (46.5%) | 88.44 (12.9%) | 89.96 (40.6%) | 90.37 (100%) |

Panel B. under no discrimination

Winner Price ratio (Frequency)

| Quality \ Price | Highest | Middle | Lowest | Total |
|---|---|---|---|---|
| Highest | 95.49 (173) | 92.56 (64) | 90.94 (169) | 93.13 (406) |
| Middle | | 71.07 (5) | 63.90 (19) | 65.40 (24) |
| Lowest | | | 71.69 (23) | 71.69 (23) |
| Total | 95.49 (174) | 91.01 (69) | 86.41 (211) | 90.57 (453) |

Winner quality score (Relative frequency)

| Quality \ Price | Highest | Middle | Lowest | Total |
|---|---|---|---|---|
| Highest | 92.11 (38.2%) | 88.98 (14.1%) | 90.14 (37.3%) | 90.80 (89.6%) |
| Middle | | 83.06 (1.1%) | 84.44 (4.2%) | 84.16 (5.3%) |
| Lowest | | | 84.77 (5.1%) | 84.77 (5.1%) |
| Total | 92.11 (38.2%) | 88.55 (15.2%) | 89.05 (46.6%) | 90.14 (100%) |

*Note.* In Panels A and B, the table shows the winner's bidding pattern in auctions that adopt MSD (Panel A) and not (Panel B). The column headers indicate whether the winner's price bid is the highest, lowest, or middle value. The row headers indicate whether the winner's quality bid is the highest, lowest, or middle value.

As previously noted, we have data on quality scores before discrimination for 73 cases of confirmed MSD. Table 8 shows the summary statistics of the winner's quality score and quality advantage pre- and post-MSD in these projects. Note that the quality score gap between the winner and the runner-up[70] is stretched out by 5 points on average

[70] We say that a bidder is a runner-up if it achieves (a) the second highest quality score when the winner is the best designer or (b) the highest quality score if the winner is not the best designer.

and the winner's quality advantage is increased by 7.8 points on average when the discrimination rule is applied. Although not reported, in 17 of these cases, the runner-up is less than a point shy from achieving the same score as the winner; these second-ranked technical proposals are likely to have similar merits and characteristics as the winner's but are deducted as much as 15 points due to the MSD rule. Such distortion in the rating system could result in the award of contract to a bidder that does not achieve the best value for money. In fact, in four of the 73 cases, one of the losers could have achieved a higher overall score than the winner if pre-MSD quality scores were used instead.[71]

As bidders are well aware of the award algorithm and evaluation criteria (including specifications of the MSD rule) used by the contracting authority before entering the auction, they can anticipate how much score advantage one would enjoy from being the best designer and would make the entry and bidding decisions considering whether or not one can be in this favorable position. This implies that bidders of MSD auctions are likely to be technically competent and put much effort to improve the quality of their technical proposals. In fact, the average quality advantage in the 73 cases pre-MSD is 5.314, while the average quality advantage under nondiscrimination is 6.59 (453 observations). The smaller difference in raw quality scores indicates that the MSD rule intensifies competition in design. Under normal circumstances, this could lead to a lower contract price because bidders would also bid aggressively in terms of price in order to avoid losing from setting

[71] The following table shows the overall total score (i.e., the weighted average of quality and price scores) of bidders using quality scores pre- and post-discrimination. Bidder 1 is the winner when the post-MSD scores are used, but other bidders can achieve higher overall scores when pre-MSD scores are used. Note that in some cases, point deduction (or addition) is applied after MSD is implemented. In project C, Bidder 2's score is adjusted downward by 7% relative to Bidder 1, then deducted 0.5 points. In project D, Bidder 2's score is adjusted downward by 10 points relative to Bidder 1, then deducted 0.05 points.

| Project | MSD rate | Bidder 1 Post-MSD | | Bidder 1 Pre-MSD | | Bidder 2 Post-MSD | | Bidder 2 Pre-MSD | | Bidder 3 Post-MSD | | Bidder 3 Pre-MSD | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Q score | Overall score | Q score | Overall score | Q score | Overall score | Q score | Overall score | Q score | Overall score | Q score | Overall score |
| A | 7 | 86.70 | 90.91 | 86.70 | 90.91 | 72.70 | 83.62 | 83.38 | 90.03 | 79.70 | 87.48 | 86.11 | 91.33 |
| B | 7 | 85.83 | 89.27 | 85.83 | 89.27 | 78.83 | 87.30 | 82.16 | 89.30 | | | | |
| C | 7 | 93.32 | 94.88 | 93.32 | 94.88 | 86.28 | 90.40 | 93.29 | 95.30 | | | | |
| D | 10 | 86.54 | 89.93 | 86.54 | 89.93 | 76.49 | 83.54 | 86.20 | 90.34 | | | | |

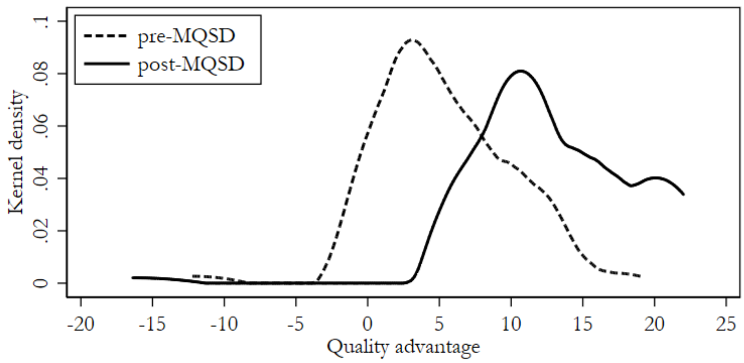
the price too high. Yet, the MSD rule leads to the opposite outcome, which will be analyzed in more detail in the results section.

Table 8. Winner's quality score pre- and post-MSD

| Variable | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| *post-discrimination:* | | | | | |
| Winner quality score | 73 | 90.51 | 5.06 | 76.64 | 100 |
| Winner quality advantage *T* | 73 | 13.122 | 5.926 | -16.368 | 22.01 |
| Quality score gap between winner and runner-up | 73 | 8.436 | 3.311 | -15 | 15 |
| *pre-discrimination:* | | | | | |
| Winner quality score | 73 | 89.731 | 3.937 | 80.44 | 97.58 |
| Winner quality advantage *T* | 73 | 5.314 | 4.697 | -12.222 | 19.11 |
| Quality score gap between winner and runner-up | 73 | 3.441 | 3.301 | -11.2 | 11 |
| *between post- and pre-discrimination:* | | | | | |
| Difference in *T* | 73 | 7.808 | 4.765 | -4.147 | 19.017 |
| Difference in score gap between winner and runner-up | 73 | 4.995 | 3.281 | -3.8 | 14.9 |

*Note.* In some cases, winner's pre- and post-MSD quality scores are not equivalent because winner's score is scaled to 100 and losers' scores are adjusted from thereafter (we found 8 such cases).

Figure 2. Kernel density estimation
of winner's quality advantage pre- and post-MSD




*Note.* The figure plots the kernel density estimation of the winner's quality advantage pre-MSD (dashed line) and post-MSD (solid line). When MSD is applied, the distribution is shifted to the right.

Figure 2 illustrates the distribution of winner's quality advantage pre- and post-MSD. The shift in the distribution to the right indicates that the rule widens the score gap between the bidders.

## 2.4 The Model

In order to understand the effect of the MSD rule on contract price, we need to compare reality with the hypothetical counterfactual scenario where there is no discrimination. One method used for counterfactual analysis is the forecasting approach, which first establishes the relationship between dependent variable and its determinants using the control group (here, non-MSD auctions) and then uses the estimated regression to predict the counterfactual value for the treatment group (here, MSD auctions). Yet, as previously noted, bidders might not behave the same way as under nondiscrimination when the MSD rule is adopted and can adjust their entry and bidding decisions considering the type and scope of discrimination. To overcome this problem, we use the two-stage forecasting method presented in Chapter 1. First, using observations of non-MSD auctions, we estimate regressions of number of bidders $N$ and quality advantage $T$. The resulting coefficient estimates are used to predict the expected number of bidders $\widehat{N}$ and the expected quality advantage $\widehat{T}$ for MSD auctions. Second, we estimate the price equation using non-MSD auctions, and we substitute the observed values of $N$ and $T$ by the expected values when predicting the counterfactual contract price of MSD. We say that the difference between the counterfactual price $\widetilde{P}$ and the observed price is the increase in procurement cost that is attributable to the discrimination rule.

The following equations are estimated:

$$P_i = \beta_0 + \beta_1 N_i + \beta_2 T_i + \beta_3 \boldsymbol{Z}_{\boldsymbol{i}}^{P} + \epsilon_{it} \qquad (1.a)$$

$$N_i = \beta_0 + \beta_1 \boldsymbol{Z}_{\boldsymbol{i}}^{N} + \epsilon_{it}, \qquad (1.b)$$

$$T_i = \beta_0 + \beta_1 N_i + \beta_2 \boldsymbol{Z}_{\boldsymbol{i}}^{T} + \epsilon_{it}. \qquad (1.c)$$

In Equation $(1.a)$, the dependent variable is logarithm of contract price for auction $i$. The set of regressors $\boldsymbol{Z}_{\boldsymbol{i}}^{P}$ includes the following variables:

- winner-specific: winner backlog ratio of current quarter
- auction-specific: logarithm of estimated price, quality weight, delivery method dummy, region dummy, government dummy, construction subcategory dummy
- market-level: CBSI

In Equation $(1.b)$, with number of bidders as the dependent variable, the set of regressors $\boldsymbol{Z}_{\boldsymbol{i}}^{N}$ contains auction- and market-related predictors as the following:

- auction-specific: logarithm of estimated price, quality weight, average backlog ratio of qualified contractors, delivery method dummy, region dummy, government dummy, construction subcategory dummy
- market-level: CBSI

In equation $(1.c)$, the dependent variable is quality advantage of the winner in auction $i$. The following variables are considered in $\boldsymbol{Z}_{\boldsymbol{i}}^{T}$:

- winner-specific: winner's relative execution capacity, logarithm of number of past projects completed successfully in the same construction subcategory
- auction-specific: logarithm of estimated price, quality weight, delivery method dummy, region dummy, government dummy, construction subcategory dummy

## 2.5 Results and Discussion

Before proceeding to our main analysis, we run regressions of $N$, $T$, and $P$ using the MSD sample, the results of which are relegated to Appendix 2.A. We include the discrimination rate (i.e., threshold value) as an explanatory variable in these regressions to check our assumptions about its relationship with the three dependent variables. In Column (1), we find that the size of discrimination rate has a strong negative effect on the number of bidders, statistically significant at the 1% level. This is consistent with our hypothesis that the MSD rule makes an auction unattractive to participate. Column (2) shows that the winner's quality advantage increases with the MSD rate and the number of bidders, while many of the other regressors do not reach statistical significance; this implies that the quality score gap depends primarily on the degree of discrimination. Column (3) and (4) provide estimates of the price equation. In the third column, it appears that the contract price is negatively associated with the discrimination rate. This may be due to the three cases in which the winner is not the best designer, so we include in Column (4) a dummy variable that indicates whether or not the winner is the best designer and an interaction term between the dummy and the MSD rate. The inclusion of these variables dissolves the statistical significance of the coefficients on the discrimination rate.

### *2.5.1 Price estimation*

Table 9 presents the main regression results (p-values in parentheses). The sample includes the 437 auctions under Weighted Criteria that are not subject to collusion nor the MSD rule. Column (1) contains estimates of Equation $(1.b)$ with number of bidders as the dependent variable. Bidder participation is positively related to project size, statistically significant at the 1% level. Although not shown, regional dummies and construction category dummies turn out to be quite significant. Column (2) gives estimates of Equation $(1.c)$, using quality advantage of the winner as the dependent variable. It is strongly negatively correlated with the estimated price, indicating that design competition becomes more aggressive with project size. It is strongly positively related to the winner's relative execution capacity and past experience variables, consistent with our expectation that a bidder with high ability is generally able to offer a superior design proposal than those that have low ability. One interesting observation is that the winner's quality advantage is positively correlated with bidder participation. One reason that the average quality score of losers decreases with the number of bidders could be that discrimination rules other than Type 4 MSD rule is taking place and discounting the quality score of non-best designers. Another explanation could be that the chance of a bidder submitting an aggressive (even predatory) bid increases with more bidders participating in the auction. Column (3) reports the regression results for Equation $(1.a)$. Contract price is positively related to the estimated price, as the cost and complexity of a project increases with its size. It is negatively correlated with the number of bidders because bidder participation intensifies competition and lowers prices. It is positively related to the winner's quality advantage, consistent with our hypothesis that there is a positive feedback between price and quality: a bidder that submits high-quality design has more flexibility in choosing price because the marginal cost of bidding slightly higher decreases with the quality score gap, while a low-quality bidder that expects a quality score disadvantage would submit a price bid of low markup in order to compensate for its weakness in design. These regression results will be used to predict the counterfactual scenario of discrimination in the next section.

Table 9. Regression results

| | (1)<br>$N$ | (2)<br>$T$ | (3)<br>$\ln(P)$ |
|---|---|---|---|
| Estimated price | 0.210*** | -1.734*** | 1.003*** |
| | (0.000) | (0.000) | (0.000) |
| Quality weight | -0.005 | -0.018 | 0.002*** |
| | (0.359) | (0.607) | (0.000) |
| Number of bidders | | 1.010** | -0.041*** |
| | | (0.013) | (0.000) |
| Winner quality advantage | | | 0.007*** |
| | | | (0.000) |
| Winner relative execution capacity | | 1.259*** | |
| | | (0.000) | |
| Winner past experience | | 1.047** | |
| | | (0.047) | |
| Winner backlog ratio | | | 0.042 |
| | | | (0.130) |
| Average backlog ratio<br>of qualified contractors | 0.278 | | |
| | (0.557) | | |
| CBSI | 0.001 | | 0.001 |
| | (0.667) | | (0.149) |
| <u>Base: Design-Build</u> | | | |
| Technical Proposal | -0.147 | 2.436** | -0.039** |
| | (0.305) | (0.013) | (0.043) |
| Alternative Bid | 0.197 | -0.120 | -0.026 |
| | (0.265) | (0.904) | (0.335) |
| Region | Yes | Yes | Yes |
| Government | Yes | Yes | Yes |
| Construction subcategory | Yes | Yes | Yes |
| Constant | -0.158 | 20.035*** | -0.307*** |
| | (0.847) | (0.000) | (0.001) |

| | | | |
|---|---|---|---|
| Observations | 437 | 437 | 435 |
| Adj. R-squared | 0.088 | 0.101 | 0.983 |
| F-statistic | 3.96 | 3.56 | 1587.82 |

*Note*. P-values are in parentheses. *, **, and *** represent 10%, 5%, and 1% significance level, respectively.

### 2.5.2 *Counterfactual outcome*

Before describing the main results of counterfactual analysis, we estimate what the winner's price bid should be if the procuring entity were to decide not to adopt the MSD rule shortly before tendering, using the 73 observations in which we have data on pre-MSD quality scores. We assume that bidders have just enough time to adjust their prices, holding all other conditions constant, such as the identity of bidders and the technical proposals they have prepared already. We thus predict the counterfactual price using the actual number of bidders and quality advantage, in conjunction with the coefficient estimates from Column (3) of Table 9 (Equation $(1.a)$). The estimated prices are reported in Table 10. Note that while the observed price ratio is 96.67% on average, the estimated price ratio using post-MSD quality advantage is 92.69%. This suggests that bidders submit even higher prices than what is expected from the post-MSD quality advantage that can be anticipated from the discrimination rate. The difference between the observed price ratio and the expected outcome using pre-MSD quality scores is even higher, suggesting that the winner inflates its price bid over 8% when the MSD rule is implemented.

Table 10. Results using Pre-MSD quality scores

| Variable | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Post-MSD quality advantage $T$ | 70 | 13.105 | 5.983 | -16.368 | 22.01 |
| Pre-MSD quality advantage $T$ | 70 | 5.432 | 4.75 | -12.222 | 19.11 |
| Winner price ratio | 70 | 96.67 | 6.5 | 63.009 | 100 |
| Expected $\widetilde{\mathrm{P}}$ ratio using Post-MSD $T$ | 70 | 92.69 | 4.648 | 74.38 | 101.928 |
| Expected $\widetilde{\mathrm{P}}$ ratio using Pre-MSD $T$ | 70 | 87.782 | 4.121 | 76.592 | 98.174 |

We now simulate what the contract price would be if the projects were procured without adopting the MSD rule. Since the MSD rule can influence who participates in an auction, we estimate the number of bidders expected to enter if there were no discrimination. We also want to estimate the counterfactual outcome of quality competition, given that a different set of bidders could participate in bidding. We impute these unknown outcomes using the results from Column (1) and (2) of Table 9, predicting the expected number of bidders $\widehat{N}$ and the expected quality advantage $\widehat{T}$. We then estimate the counterfactual price of MSD using the coefficient estimates from Column (3). The estimated outcomes of $N$, $T$, and $P$ are presented in Panel A of Table 11. The results imply that if there were no discrimination, number of bidders would slightly increase (not statistically significant), and winner's quality advantage would be cut by more than half (statistically significant at the 1% level); there is also a substantial difference between the observed and expected price ratios (statistically significant at the 1% level). The effect on the number of bidders appears limited, but what is important is the technical capacity of bidders that have and would have entered under MSD and nondiscrimination. In Section 2.3, Panel B of Table 6 shows that auctions under MSD often have more than two bidders and they are more homogeneous in terms of execution capacity than under nondiscrimination. In those cases, winner's execution capacity relative to qualified contractors is also small on average, suggesting that bidders are likely to be similarly technically competent even when the MSD rule is not present.

Table 11. Results of counterfactual analysis

Panel A. Estimated outcomes

| Variable | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Number of bidders | 99 | 2.424 | .591 | 2 | 4 |
| Expected $\widehat{N}$ | 99 | 2.486 | .288 | 1.722 | 2.955 |
| Winner quality advantage | 99 | 12.881 | 5.697 | -16.368 | 25 |
| Expected $\widehat{T}$ | 99 | 3.811 | 2.858 | -2.424 | 9.964 |
| Winner price ratio | 99 | 96.531 | 6.11 | 63.009 | 100 |
| Expected winner $\widetilde{P}$ ratio | 99 | 86.584 | 4.158 | 76.445 | 95.727 |

Panel B1. Cost increase ratio by winning scenario

| Pattern | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| All | 99 | 9.857 | 8.407 | -33.165 | 21.121 |
| HQ/HP | 46 | 10.682 | 5.624 | -6.761 | 21.121 |
| HQ/LP | 39 | 9.871 | 9.396 | -26.916 | 20.532 |
| HQ/MP | 13 | 10.203 | 4.69 | 2.41 | 15.72 |
| LQ/LP | 1 | -33.165 | . | -33.165 | -33.165 |

Panel B2. Cost increase ratio by discrimination rate

| Rate | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| 5 | 3 | 3.446 | 1.359 | 2.361 | 4.97 |
| 7 | 49 | 11.318 | 5.373 | -4.721 | 21.121 |
| 8 | 4 | 13.535 | 2.445 | 10.21 | 15.72 |
| 8.5 | 1 | 15.686 | . | 15.686 | 15.686 |
| 10 | 39 | 9.041 | 9.347 | -26.916 | 18.349 |
| 15 | 3 | -3.845 | 25.436 | -33.165 | 12.309 |

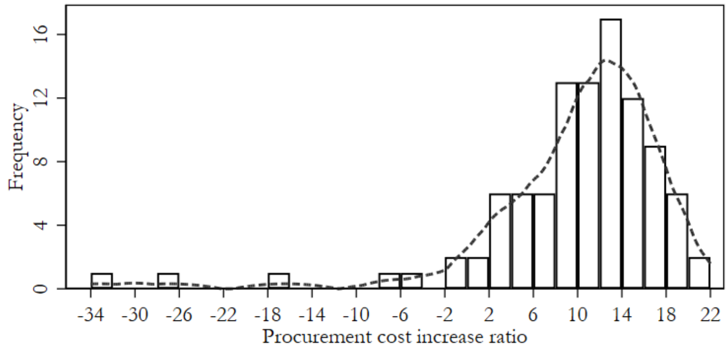
The estimated cost increase ratios for the 99 confirmed MSD cases are displayed in Panels B1 and B2 of Table 11 (see Appendix 2.C and Appendix 2.D for the results of unconfirmed MSD cases). A cost increase ratio is defined as the difference between $\tilde{P}$ and contract price divided by contract price and multiplied by 100%, showing the increase in procurement cost attributable to the MSD rule in percentage terms. The estimated ratio ranges from -33.165% to 21.121%, with an average of 9.86%. The distribution of estimates is illustrated in Figure 3. Notice that there are seven projects in which the estimate is negative, including the one case where a non-best designer (LQ/LP) is awarded the contract.[72] Without them, the average of the estimates increases to 11.58%. The result shown in Panel B2 of Table 11 suggests that the cost increase ratio is not necessarily increasing with the discrimination rate.[73] This does not support our hypothesis that the greater is the distortion in quality scores, the lower is the incentive for bidders to compete

[72] The average size of the seven projects is 99.7 billion KRW, considerably lower than other projects in the sample (183.4 billion KRW). As the extent of price increase due to MSD may depend on project size, we estimate the cost increase ratio weighted by contract price. The average of the estimates increases to 11.24%, suggesting that bidders inflate prices even higher in large-scale projects.

[73] Five out of the seven cases in which the estimate is negative have an MSD rate of 10%; without them, the average ratio increases to 11.88% when the rate is 10%, which is slightly higher than the average ratio of 11.65% when the rate is 7%.

in terms of price. This may be due to the difficulty of bidders to identify their optimal bidding strategy when an interdependent scoring rule is applied. Even if the bidders can roughly figure their technical ranking, the bidder that anticipates being the best designer may not be able to raise its price bid substantially when the discrimination rate is high in fear that other bidders would submit aggressive prices. There also could be fundamental differences between contracting authorities in their decision to adopt the rule for a particular project.

Figure 3. Frequency of cost increase ratios




*Note.* This histogram shows the frequency of cost increase ratios. The dashed line is the kernel density estimate of the distribution.

In Appendix 2.D, we assess the sensitivity of the results. We analyze five different model specifications: (A) using execution capacity relative to losers instead of qualified contractors; (B) limit the sample to projects procured since 2013; (C) limit the sample to projects procured before 2013; (D) restrict the sample to projects in the field of civil engineering; and (E) restrict the sample to projects in the field of architecture. In (A), we construct the counterfactual assuming that the same bidders participate in the auction whether or not the MSD rule is present. We thus use the observed number of bidders and the observed winner's execution capacity relative to losers in the estimation of contract price. The estimates of cost increase ratio decrease slightly, with an average of 9.34%, but the distribution remains similar. Under specifications (B) and (D), the average cost increase ratio is 5.12% and 8.16%, respectively, with more cases of negative estimates, but these estimates could be biased due to small sample size. These results show that the main finding remains consistent across specifications.[74]

Another area that needs further research is how the implementation of the MSD rule influences quality competition and quality bids. Caution is warranted when comparing quality scores across auctions because design evaluation is subjective and depends on the type and complexity of construction work, the choice of evaluation criteria, and by whom and how each criterion is scored. For the sake of comparison with the results on the price side, we estimate the winner's quality score in a hypothetical scenario where there is no discrimination. The results shown in Appendix 2.C suggest that the MSD rule leads to an increase in winner's quality score of 0.67 point on average. Although we need to be careful in interpreting this result, the fact that, on average, there is less than a point difference in the quality dimension but more than a 5-percentage point difference in the price dimension between the two regimes casts serious doubts about the efficiency and tenability of the discrimination rule.

## 2.6 Conclusion

A minimum score discrimination (MSD) rule is an interdependent scoring method that has been developed and implemented exclusively in Korea. Under this rule, quality scores of technical proposals are adjusted at the end of the evaluation such that the distance between them is at least as wide as a predefined discrimination rate. This method has several advantages: it creates more differentiation between quality scores so that the contracting authority is better able to determine the hierarchy of design proposals, and it fosters competition in quality so that bidders are discouraged from engaging in predatory pricing behavior. However, there are serious downsides to adopting the MSD rule. First, it makes it difficult for a bidder to determine the score and rank of its own bid. Bidders cannot introspect over their costs and valuations and determine the bidding strategy that can achieve the highest score. In consequence, the contract could be awarded to a bidder that

[74] The cost increase ratio is much greater in the confirmed MSD sample than in the unconfirmed sample across specifications. This suggests that discrimination rules other than Type 4 might actually be in effect in some of the unconfirmed cases.

does not provide the best value for money. Second, it discriminates against weak designers in favor of strong designers. The bidder that achieves the highest quality score enjoys a score advantage that may not be easy to overcome by lowering prices. Consequently, it could discourage participation of bidders and drive up the overall price level of the winning bid. In the case of public projects, the decrease in the pressure of price competition raises serious concerns because it could translate into inefficient spending of taxpayer dollars.

To our knowledge, this is the first study to provide empirical evidence on the potential harm of using a discriminatory rating system in the evaluation of technical proposals. We analyze how bidders respond to the MSD rule in multi-attribute public procurement auctions by simulating a counterfactual situation where there is no discrimination. We develop a two-stage forecasting model as follows: in the first stage, we use observations of non-MSD auctions to derive the underlying equation of number of bidders and winner's quality advantage; then, we estimate the expected outcomes of the two variables when there is discrimination for MSD auctions. In the second stage, we estimate the price function using non-MSD auctions, and we substitute the estimates from the first stage for the actual values when estimating the counterfactual price for MSD auctions. The imputation of missing data in the first stage is essential for the construction of the counterfactual scenario.

The counterfactual analysis suggests that in the 99 projects procured between 2010-2020, the adoption of the MSD rule leads to on average a 9.86% increase in procurement cost. This means that an additional burden of roughly 1,900 billion KRW is imposed on taxpayers to deliver these projects. There are some variations in the estimates depending on the model specification, but the economic significance of the estimates is considerable in all cases. Procuring officials thus should be more cautious about applying the MSD rule and search for alternative options, such as increasing the quality weight, to achieve their goals and objectives. Lastly, we suggest two areas where future research is required. The first is to explore the theoretical properties of MSD auctions and to model bidding behavior within a mechanism design framework. The second is to give a comprehensive analysis of the risks and benefits associated with different types of MSD rules.

# Appendix 2

## Appendix 2.A

Preliminary regression results (using MSD sample)

| | (1)<br>$N$ | (2)<br>$T$ | (3)<br>$\ln(P)$ | (4)<br>$\ln(P)$ |
|---|---|---|---|---|
| MSD rate | -0.049*** | 1.398*** | -0.019*** | 0.006 |
| | (0.002) | (0.000) | (0.000) | (0.610) |
| Winner best designer | | | | 0.322** |
| | | | | (0.036) |
| MSD rate * Winner best designer | | | | -0.021 |
| | | | | (0.121) |
| Estimated price | 0.115 | 0.559 | 1.001*** | 1.001*** |
| | (0.115) | (0.339) | (0.000) | (0.000) |
| Quality weight | -0.011 | 0.121** | 0.001 | 0.001 |
| | (0.156) | (0.038) | (0.303) | (0.248) |
| Number of bidders | | 5.674*** | -0.091*** | -0.075*** |
| | | (0.000) | (0.000) | (0.000) |
| Winner quality advantage | | | 0.012*** | 0.009*** |
| | | | (0.000) | (0.001) |
| Winner relative execution capacity | | 0.915* | | |
| | | (0.087) | | |
| Winner past experience | | 0.331 | | |
| | | (0.639) | | |
| Winner backlog ratio | | | 0.027 | 0.030 |
| | | | (0.199) | (0.139) |
| Average backlog ratio of qualified contractors | 0.161 | | | |
| | (0.709) | | | |
| CBSI | -0.003 | | -0.000 | -0.000 |
| | (0.479) | | (0.514) | (0.437) |
| Base: Design-Build | | | | |
| Technical Proposal | 0.067 | 0.164 | -0.014 | -0.008 |
| | (0.607) | (0.803) | (0.326) | (0.559) |
| Alternative Bid | 0.111 | 0.626 | -0.030* | -0.031 |
| | (0.689) | (0.499) | (0.089) | (0.100) |
| Region | Yes | Yes | Yes | Yes |
| Government | Yes | Yes | Yes | Yes |
| Construction subcategory | Yes | Yes | Yes | Yes |
| Constant | 2.071** | -25.945*** | 0.165* | -0.200 |
| | (0.024) | (0.000) | (0.052) | (0.251) |
| Observations | 186 | 186 | 184 | 184 |
| Adj. R-squared | 0.070 | 0.563 | 0.995 | 0.995 |
| F-statistic | 2.76 | 22.29 | 2908.09 | 2940.50 |

*Note.* P-values are in parentheses. *, **, and *** represent 10%, 5%, and 1% significance level, respectively.

Appendix 2.B

Other specifications

| | (1)<br>$N$ | (2)<br>Quality advantage excluded<br>$\ln(P)$ |
|---|---|---|
| Estimated price | 0.210*** | 0.993*** |
| | (0.000) | (0.000) |
| Quality weight | -0.005 | 0.002*** |
| | (0.359) | (0.000) |
| Number of bidders | | -0.034*** |
| | | (0.000) |
| Winner quality advantage | | |
| Winner relative execution capacity | | |
| Winner past experience | | |
| Winner backlog ratio | | 0.040 |
| | | (0.200) |
| Average backlog ratio of qualified contractors | 0.278 | |
| | (0.557) | |
| CBSI | 0.001 | 0.000 |
| | (0.667) | (0.189) |
| Base: Design-Build | | |
| Technical Proposal | -0.147 | -0.020 |
| | (0.305) | (0.311) |
| Alternative Bid | 0.197 | -0.027 |
| | (0.265) | (0.335) |
| Region dummy | Yes | Yes |
| Government dummy | Yes | Yes |
| Construction subcategory dummy | Yes | Yes |
| Constant | -0.158 | -0.185* |
| | (0.847) | (0.054) |
| Observations | 437 | 435 |
| Adj. R-squared | 0.088 | 0.981 |
| F-statistic | 3.96 | 1509.75 |

*Note.* P-values are in parentheses. *, **, and *** represent 10%, 5%, and 1% significance level, respectively.

Appendix 2.C

As quality assessment is highly subjective in its nature, we need to be careful about comparing quality scores across auctions. Yet, for the sake of contrast with the results we found on the price side, we construct the counterfactual scenario where the MSD rule is not implemented on the quality side. The model is expressed as follows:

$$Q_i = \beta_0 + \beta_1 N_i + \beta_2 T_i + \beta_3 \boldsymbol{Z}_{\boldsymbol{i}}^{Q} + \epsilon_{it}, \qquad (1.d)$$

where the dependent variable $Q_i$ is the winner's quality score (or auction average quality score) in auction $i$. The unobserved attributes are captured by the residual term. Number of bidders and winner's quality advantage are denoted by $N_i$ and $T_i$, respectively. The set of regressors $\boldsymbol{Z}_{\boldsymbol{i}}^{Q}$ includes the following: logarithm of estimated price, quality weight, winner backlog ratio of current quarter, difference in execution capacity between winner and qualified contractors, logarithm of number of past projects completed successfully in the same construction subcategory, delivery method dummy, region dummy, government dummy, and construction subcategory dummy.

The regression results are shown in the table below. We need to be careful about interpreting the magnitude of coefficients because design evaluation varies from auction to auction. Yet, it is noteworthy that the direction of coefficients are consistent with our expectations. Quality scores are negatively correlated with estimated price because the complexity of a project is likely to increase with project size. They are positively correlated with quality weight because it reflects the relative importance of technical criteria. The result of column (1) implies that a percentage point increase in quality weight is associated with a 0.137 point increase in winner's quality score. Quality scores are strongly negatively correlated with the number of bidders because there can be MSD rules other than Type 4 taking place that increases the spread of quality scores; also, as more bidders enter, it is more likely that some of them compete aggressively in price, which may pull the average quality level downward. Lastly, we find that winner's quality score increases with its performance records and quality advantage, while auction average quality score is negatively correlated with winner's quality advantage.

Regression results

| | (1) Winner Q | (2) Average Q |
|---|---|---|
| Estimated price | -0.606** | -0.618** |
| | (0.042) | (0.031) |
| Quality weight | 0.137*** | 0.128*** |
| | (0.000) | (0.000) |
| Number of bidders | -1.598*** | -2.226*** |
| | (0.000) | (0.000) |
| Winner quality advantage | 0.208*** | -0.250*** |
| | (0.000) | (0.000) |
| Winner relative execution capacity | 0.937** | 0.900** |
| | (0.016) | (0.013) |
| Winner past experience | 1.590 | 1.467 |
| | (0.177) | (0.187) |
| Winner backlog ratio | 0.102 | 0.118 |
| | (0.711) | (0.659) |
| Base: Design-Build | | |
| Technical Proposal | -1.169 | -0.918 |
| | (0.174) | (0.261) |
| Alternative Bid | -1.201* | -1.104* |
| | (0.074) | (0.074) |
| Region | Yes | Yes |
| Government | Yes | Yes |
| Construction subcategory | Yes | Yes |
| Constant | 93.040*** | 94.986*** |
| | (0.000) | (0.000) |
| Observations | 435 | 435 |
| Adj. R-squared | 0.297 | 0.364 |
| F-statistic | 8.89 | 13.23 |

*Note.* P-values are in parentheses. *, **, and *** represent 10%, 5%, and 1% significance level, respectively.

The below table presents the outcome of the counterfactual simulation. The results indicate that the MSD rule leads to an increase in winner's quality score of 1.5 point on average for the confirmed and unconfirmed samples combined. In order to achieve the same effect, the contracting authority can increase the quality weight by 10.945 percentage points, which is followed by only a 0.025 percentage point increase in contract price. The effect may be slightly underestimated due to the three cases of LQ/LP (one confirmed and two unconfirmed cases). The substantial decrease in quality score when the winner is not the best designer suggests that the MSD rule can intensify the injurious effect of price dumping on procurement, contrary to its purpose. If we only consider the confirmed cases of MSD, the average increase in winner's quality score due to MSD is 0.67 point. The contracting authority can achieve equivalent effect by increasing the quality weight by 4.89 percentage points on average, which is associated with only a 0.011 percentage point increase in contract price.

Results of counterfactual analysis

Panel A. Quality score increase by winning scenario

| pattern | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| All | 184 | 1.494 | 5.117 | -17.617 | 12.172 |
| HQ/HP | 94 | 1.945 | 4.663 | -7.344 | 12.172 |
| HQ/LP | 67 | 1.998 | 4.716 | -8.759 | 11.571 |
| HQ/MP | 20 | -.418 | 5.846 | -10.969 | 10.973 |
| LQ/LP | 3 | -11.137 | 5.636 | -17.617 | -7.377 |

Panel B. Results of confirmed and unconfirmed cases

| | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Quality score increase (point) | 184 | 1.494 | 5.117 | -17.617 | 12.172 |
| - Quality weight equivalent (%) | 184 | 10.945 | 37.481 | -129.044 | 89.16 |
| Confirmed: | | | | | |
| Winner Q | 99 | 90.41 | 4.991 | 76.64 | 100 |
| Expected winner $\widehat{Q}$ | 99 | 89.742 | 2.095 | 84.017 | 95.296 |
| Quality score increase (point) | 99 | .668 | 5.18 | -10.969 | 11.752 |
| - Quality weight equivalent (%) | 99 | 4.89 | 37.941 | -80.347 | 86.085 |
| Unconfirmed: | | | | | |
| Winner Q | 85 | 93.314 | 4.963 | 70.78 | 100 |
| Expected winner $\widehat{Q}$ | 85 | 90.857 | 2.418 | 85.513 | 96.79 |
| Quality score increase (point) | 85 | 2.457 | 4.898 | -17.617 | 12.172 |
| - Quality weight equivalent (%) | 85 | 17.998 | 35.881 | -129.044 | 89.16 |

Appendix 2.D

The baseline results imply that the adoption of MSD leads to a 9.86% and 2.12% increase in procurement cost while a 0.67-point and 2.46-point increase in quality score, respectively, for the confirmed and unconfirmed samples combined.

Comparison of estimates across specifications

Baseline model specification
(estimated with 435 non-MSD observations)

| | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Cost increase ratio (%) | 184 | 6.284 | 11.088 | -93.384 | 21.121 |
| Quality score increase (point) | 184 | 1.494 | 5.117 | -17.617 | 12.172 |
| Confirmed: | | | | | |
| - Cost increase ratio (%) | 99 | 9.857 | 8.407 | -33.165 | 21.121 |
| - Quality score increase (point) | 99 | .668 | 5.18 | -10.969 | 11.752 |
| Unconfirmed: | | | | | |
| - Cost increase ratio (%) | 85 | 2.123 | 12.363 | -93.384 | 14.377 |
| - Quality score increase (point) | 85 | 2.457 | 4.898 | -17.617 | 12.172 |

A. Using given number of bidders and winner execution capacity relative to losers
(estimated with 434 non-MSD observations)

| | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Cost increase ratio (%) | 183 | 5.596 | 11.044 | -91.478 | 23.383 |
| Quality score increase (point) | 183 | 1.177 | 4.918 | -16.657 | 12.074 |
| Confirmed: | | | | | |
| - Cost increase ratio (%) | 99 | 9.342 | 8.565 | -37.461 | 23.383 |
| - Quality score increase (point) | 99 | .397 | 5.081 | -10.552 | 12.074 |
| Unconfirmed: | | | | | |
| - Cost increase ratio (%) | 84 | 1.18 | 12.016 | -91.478 | 16.453 |
| - Quality score increase (point) | 84 | 2.096 | 4.581 | -16.657 | 10.952 |

B. Procured since 2013
(estimated with 112 non-MSD observations)

| | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Cost increase ratio (%) | 113 | 4.023 | 12.54 | -42.128 | 26.768 |
| Quality score increase (point) | 113 | .66 | 7.721 | -17.108 | 18.133 |
| Confirmed: | | | | | |
| - Cost increase ratio (%) | 92 | 5.117 | 12.053 | -40.31 | 24.948 |
| - Quality score increase (point) | 92 | -.137 | 7.4 | -17.108 | 15.549 |
| Unconfirmed: | | | | | |
| - Cost increase ratio (%) | 21 | -.767 | 13.785 | -42.128 | 26.768 |
| - Quality score increase (point) | 21 | 3.096 | 6.867 | -7.143 | 13.646 |

C. Procured before 2013
(estimated with 326 non-MSD observations)

| | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Cost increase ratio (%) | 71 | 1.108 | 13.343 | -96.167 | 14.739 |
| Quality score increase (point) | 71 | 2.604 | 5.514 | -18.052 | 11.184 |
| Confirmed: | | | | | |
| - Cost increase ratio (%) | 7 | 8.872 | 4.502 | 3.111 | 14.739 |
| - Quality score increase (point) | 7 | 5.733 | 7.868 | -11.169 | 11.184 |
| Unconfirmed: | | | | | |
| - Cost increase ratio (%) | 64 | .258 | 13.728 | -96.167 | 10.394 |
| - Quality score increase (point) | 64 | 2.261 | 5.165 | -18.052 | 11.097 |

D. Civil engineering
(estimated with 159 non-MSD observations)

| | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Cost increase ratio (%) | 98 | 6.099 | 14.561 | -105.364 | 21.569 |
| Quality score increase (point) | 98 | 1.249 | 5.873 | -20.131 | 13.625 |
| Confirmed: | | | | | |
| - Cost increase ratio (%) | 70 | 8.159 | 9.736 | -33.355 | 21.569 |
| - Quality score increase (point) | 70 | .893 | 5.878 | -10.641 | 13.625 |
| Unconfirmed: | | | | | |
| - Cost increase ratio (%) | 28 | .948 | 21.932 | -105.364 | 14.857 |
| - Quality score increase (point) | 28 | 2.138 | 5.87 | -20.131 | 10.348 |

E. Architecture
(estimated with 197 non-MSD observations)

| | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Cost increase ratio (%) | 61 | 1.865 | 5.862 | -27.243 | 12.342 |
| Quality score increase (point) | 61 | 2.306 | 4.939 | -11.484 | 11.798 |
| Confirmed: | | | | | |
| - Cost increase ratio (%) | 20 | 3.113 | 8.165 | -27.243 | 12.342 |
| - Quality score increase (point) | 20 | .513 | 5.708 | -11.484 | 11.798 |
| Unconfirmed: | | | | | |
| - Cost increase ratio (%) | 41 | 1.257 | 4.326 | -14.998 | 12.178 |
| - Quality score increase (point) | 41 | 3.181 | 4.327 | -6.45 | 10.024 |

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# 국문 초록

# 다차원 공공입찰에서의 담합과 경쟁에 대한 연구



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본 논문은 한국의 공공공사 기술형 입찰에서 발생하는 두가지 상황—입찰담합과 강제차등제도—을 연구한다. 공공조달의 목표는 물품을 금액 대비 최선의 가치(best value for money)로 구매하는 것이나, 두 상황 하에서는 최적 이하의 결과가 나타날 수 있다. 본 논문은 2 단계 예측접근법을 이용해 담합/차등제가 없었다면 발생했을 가상 시나리오를 제시하고 실제로 관측된 결과와 비교하여 두 상황이 조달시장에 미치는 효과를 추정한다. 구체적으로, 1 단계에서 차등제가 적용되지 않은 비담합 입찰(비교집단)을 이용해 입찰자수와 설계점수차이 모형을 추정하고, 산출된 추정식을 이용해 담합/차등제 적용집단의 가상상황 예측치를 구한다. 2 단계에서는 비교집단을 이용해 낙찰가격 모형을 추정하고, 1 단계에서 구한 적용집단의 예측치와 특성변수를 대입하여 가상상황 낙찰가격을 추정한다. 2 단계 예측접근법은 기존의 방식과는 달리 비가격 요소에 미치는 효과를 통제하고 입찰자 시공능력 등 새로운 변수를 추가로 고려하여 반사실적 (counterfactual) 분석의 예측력을 한층 높일 수 있다.

첫번째 챕터는 담합이 입찰결과에 미치는 효과를 분석하여 다음과 같은 세가지 결과를 도출하였다. 첫째로, 담합행위가 경쟁을 제한하여 입찰자수를 줄이고 설계점수차를 상승시키는 결과를 초래했다. 따라서 본 논문이 낙찰가격 모형에서 두 변수의 관측치를 그대로 사용하는 대신에 2 단계 예측접근법으로 분석한 이유를 설명할 수 있다. 둘째로, 실현된 가격과 가상 경쟁 가격 추정치를 비교했을 때 담합행위가 낙찰가 대비 평균 7.78%의 손해율을 발생시키는 것을 밝혔다. 이는 민감도 분석에서도 대체로 일관된 결과를 보였다. 셋째로, 담합사건을 유형별로—가격합의, 들러리입찰, 공구분할—구분하여 비교했을 때 여러 건의 공사에 대한 합의가 이루어질 때 손해율이 더 크다는 것을 밝혔다. 이는 담합행위의 규모와 가담자의 특성 및 의도와 연관된 것으로 보이며 더 정확한 규칙성을 찾기 위해서는 추가적인 연구가 필요할 것이다.

두번째 챕터는 기존의 연구에서는 논의된 적이 없었던 설계점수 강제차등제를 살펴보았다. 총점차등제는 설계점수 순위에 따라 최대 15%까지 강제로 격차를 벌리는 상호의존적인 점수산정 방식이다. 이는 고품질 설계가 가능한 기업에 유리하게 작용하여 경매의 진입장벽을 높이고 입찰자가 가격경쟁을 할 여지를 줄여 조달비용을 상승시킬 수 있다. 2 단계 예측접근법을 이용해 제도가 도입되지 않았다면 발생했을 가상 가격과 실현된 가격을 비교했을 때 총점차등제가 계약가격을 평균 9.86% 증가시키는 것을 밝혔다. 이는 강제차등제가 국가예산의 낭비를 초래할 수 있으며 발주기관은 제도의 리스크와 비용을 충분히 검토한 후 적용할 필요가 있다는 점을 시사한다. 본 연구는 입찰자료와 표본 수의 크기가 제한되어 있는 한계를 지니고 있지만, 강제차등제를 연구한 첫 시도라는 점에서 의의를 지닌다.

**주 요 어:** 역경매, 조달경매, 다차원 경매, 건설산업, 턴키, 일괄입찰, 입찰담합, 강제차등점수제

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