Endogenous Joint Venture Formation in Procurement Auctions*

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Very Preliminary
Please find the updated version here.

Abstract

We examine the influence of joint ventures on procurement efficiency. On one hand, the government anticipates the cost synergies derived from such collaborations. On the other hand, this strength diminishes the incentive for new entrants, resulting in a decrease in the total number of bidders. We estimate a two-stage structural model to simulate the balance between these two forces. Our model provides evidence of the existence of cost synergies and quantifies two obstacles to joint venture formation: adjustment costs and search frictions. While these obstacles partially mitigate the anti-competitive path, our simulation demonstrates that excessive promotion of joint venture formation by the government leads to a reduction in procurement efficiency.

JEL Classification Codes: L24; D22; D44; H57.
Keywords: Joint ventures; Cost synergies; Matching; Procurement auctions.

1 Introduction

In government procurement, many countries allow firms to participate in auctions as a joint venture with the goal of creating cost synergies among the forming firms and promoting the entry of construction firms who could not enter otherwise; This may increase the total

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number of bidders and make their bids more competitive. However, joint bidding may reduce the number of bidders. As a direct effect, the auction loses one bidder as two individual firms submit one bid jointly. As an indirect effect, if joint ventures have cost synergies, individual bidders may be discouraged from participating in the auctions as they would face stronger competitors. Examining the trade-off between cost synergies and reduced competition is therefore key to understand the welfare implication of joint ventures.

The pro-competitiveness of joint ventures in several countries, including Japan and Austria, and EU has been empirically supported in the literature (Iimi, 2004; Estache and Iimi, 2009; Branzoli and Decarolis, 2015; Gugler, Weichselbaumer and Zulehner, 2021). While these studies have primarily focused on the cost synergies resulting from joint ventures and their impact on procurement efficiency, little attention has been given to the effect of joint ventures on market entry incentives within an integrated model. Thus, the primary objective of our study is to develop an integrated model that encompasses market entry, joint venture formation, and procurement auction bidding, and to identify the sources of pro-competitive and anti-competitive effects.

Our model consists of two stages: (i) the entry and joint venture formation stage and (ii) the bidding stage where the bidders engage in a scoring auction. The main focus of our model is the first stage, where potential entrants decides whether they enter or not as well as the mode of entry, i.e., enter as a single bidder or as a joint venture. The formation of joint venture involves search friction, transaction costs, and externalities; (1) potential entrants face search friction in finding a suitable partner to form a joint venture, (2) potential entrants incur additional managerial costs to form a joint venture, and (3) the number of joint ventures affects the incentive/strategy of bidders in the subsequent auction as well as the outcome of the auction.[1] We build a tractable model of group formation with externality, which is applicable to broader research topics such as mergers and matching markets. The second stage is modeled as an asymmetric scoring auction with two dimensional private information: the construction cost and the auction score.

[1]Modeling search friction and transaction costs are motivated by our observation that joint ventures appear in only 14% of 'large' scale auctions and a finding in (Gugler, Weichselbaumer and Zulehner, 2021) that joint bids account for only 5% of total bids in Austria, though the value share is much bigger. Such limited practices of joint bidding in reality suggests some costs associated with joint venture formation and our model capture them through search friction and transaction costs.

In addition, our structural model enables us to identify obstacles that hinder the formation of joint ventures which causes the few number of successfully formed joint ventures. Despite governments occasionally encourage joint ventures, joint bidding is not frequently observed, as exemplified by the fact that joint bids account for only 5% of total bids in Austria (Gugler, Weichselbaumer and Zulehner, 2021). Given that the literature shows joint ventures can generate synergies and provide potential bidders with the ability to enter markets, the limited practice of joint bidding suggests the existence of countervailing power that hinders joint venture formation. We quantify this obstacle using our model and decompose it into two elements: additional entry cost arising from the management of the joint venture and search friction in finding suitable partners.

We estimate the model from the second stage. We first recover the individual cost factors given the observed scores and then jointly plot the recovered cost factors and scores for single bidders and joint ventures, separately. The distributions do not match each other, which implies that the distributions of cost factors are different, the distributions of score are different, or both of them are different for single bidders and joint ventures. When looking at the score distributions depending on the mode of entry, the distributions are almost identical, enabling us to conclude that the difference are mainly driven by the cost factor distributions. Therefore, these results show the evidence that there exists a certain degree of cost synergy generated by forming a joint venture.

The entry and joint venture formation stage involves two objects of interest: (1) entry costs for single bidders and joint ventures, and (2) the friction in joint venture formation. In our estimation, we find that the joint ventures incur higher entry costs than the single bidders do. This is an evidence of the adjustment costs for managing joint ventures, as known in the literature of the merger (Graebner et al., 2017). We also estimate the function that maps the number of potential entrants intending to form a joint venture to the number of successfully formed joint ventures. Under the estimated model, we observe the evidence for the search friction that not all entrants intending to form a joint venture can form a joint venture and the number of realized joint ventures may not increase in proportion to the number of bidders attempting to form them.

The counterfactual simulation evaluates procurement efficiency through varying joint venture participation by either increasing or decreasing joint ventures' entry cost. Our analysis reveals that a mild reduction in the entry cost significantly enhances procurement efficiency. The excessive reductions in entry cost lead to intensified competition among joint ventures, reducing the likelihood of single bidders winning the auction. This subsequently decreases the total number of bidders, outweighing the pro-competitive effect of the cost synergies generated by joint ventures.

1.1 Related Literature

Joint bidding is intensively studied in the context of common value auction where the auctioneer sells a natural resource like petroleum. The empirical and theoretical results about the competitive effect of joint bidding are mixed. Mead (1967) and Levin (2004) argue that the joint bidding plays like a bidding rings or a collusion and hence impedes the competitive bids among the bidders. Millsaps and Ott (1985), Moody and Kruvant (1988), and Hendricks and Porter (1992) indicate the pro-competitive effects of joint bidding caused by pooling information, relaxing the budget constraint and risk sharing.

The theoretical literature on joint bidding is extended to include another form of auctions like a patent auction (Asker, Baccara and Lee, 2021), the private value auctions (Cho, Jewell and Vohra, 2002; Cantillon, 2008; Chatterjee, Mitra and Mukherjee, 2017) and the auction with subcontracting (Bouckaert and Van Moer, 2021). These models are tailored to the specific application. Empirical studies on the joint bidding are carried out almost independently from the theoretical literature (Iimi, 2004; Estache and Iimi, 2009; Branzoli and Decarolis, 2015). These papers show the reduced form evidence to support the pro-competitive effect of joint bidding.

The literature on merger or joint venture in other context considers the similar problem as the problem of joint venture in auction. Weese (2015); Akkus, Cookson and Horta¥ccsu (2016); Uetake and Watanabe (2020) consider the model of matching market in several different areas. These papers estimate the effect of matching using moment inequality approach developed by Fox (2018); Pakes (2010) due to the multiple equilibrium. In contrast to these literature, we develop a model which has unique equilibrium in the entry stage, i.e., joint venture formation stage. Miller and Weinberg (2017) is one example of papers which treats the competition after forming a group. This paper focus on the joint venture in beer industry which come to produce one item jointly after the formation. Their method is similar to the conduct parameter approach which is not applicable to the current context.

The closest study to ours is Gugler, Weichselbaumer and Zulehner (2021), which carries out a structural estimation of the auction with joint bidding. They focus on the types of the firms to form a joint venture and analyze the difference between the case of restricting all joint ventures and the case in which joint venture is allowed only to the small-sized firms to conclude that the joint venture by large-sized firms is the driving force of pro-competitive effect. In contrast to this study, we do not use the identity of the firm in our analysis. Instead we focus only on the number of joint ventures and the single bidders in each auction. Though this is a data limitation, our model can assure the unique equilibrium in the entry stage which is not guaranteed in Gugler, Weichselbaumer and Zulehner (2021). Additionally, we put a focus on the adjustment cost to form a joint venture while Gugler, Weichselbaumer and Zulehner (2021)does not care about this point.

We consider the first-price sealed bid scoring auction. As the similar class of auctions, Krasnokutskaya and Seim (2011) study the first-price auction with bid preference. They point out that the bid preference in the bidding stage distorts the incentive to entry of the unfavored group and argue that the careful setting of the bid preference is necessary to achieve both the efficient procurement and improving the minority status. Other papers also insist on this point (Corns and Schotter, 1999; Marion, 2007; Athey, Coey and Levin, 2013; Nakabayashi, 2013; Rosa, 2019). All of these studies focus on the bid preference for the small-sized firms: in the bidding stage, the firms categorized as "small-sized" according to the number of employees or the size of the budget get favored by weighting their bid at a fixed rate. While our paper also considers the relationship between the bid preference in the bidding stage and the entry behavior in the entry stage, the situation is different from these existing ones: the first point is that the bid preference is based on the score which is determined by the characteristics of the entrant such as the size, whether or not the entrant is a local one, and whether or not the entrant is joint venture, i.e., our bid preference is much more complicated. The second point is that the potential bidders can decide to get favored in the bidding stage by forming a joint venture. This endogeneous nature is not considered in the previous literature.

The last contribution of this paper is the empirical evidence of the adjustment cost when two or more firms form a consortium. This is a well-studied topic in management science, surveyed in (Graebner et al., 2017). To generate synergy by forming a joint venture or after merger, it is essential to adjust the culture and the customs among the related firms (Chatterjee et al., 1992; Stahl and Voigt, 2008; Reus and Lamont, 2009). And the knowledge transfer, which is obviously necessary to make a synergy, requires a lot communication (Larsson and Finkelstein, 1999; Bresman, Birkinshaw and Nobel, 2010). We think the adjustment cost of this paper is an expression of this type of behavior. While almost all the discussions in the existing literature is qualitative ones, we contribute a new quantitative evidence to the existence and the size of this cost to from a consortium.

The first strand of the literature that this paper contributes to is the empirical literature on joint venture formation and endogeneous merger formation. Forming a joint venture and mergers share some similarities where parties commit to make a collective decision with a difference that the joint venture can be a temporary commitment. The competitive effect of joint venture has been studied intensively as in the merger literature, e.g., Shapiro and Willig (1990), Estache and Iimi (2009) and Miller and Weinberg (2017). The incentives for mergers and for joint venture formation are complex including externalities in the subsequent competition, which makes it challenging to build a tractable and internally-consistent model. The literature has developed in two strands: (i) building a long time horizon dynamic model as in Gowrisankaran (1999) and Igami and Uetake (2020), and (ii) utilizing the matching model, developed by Fox (2018), as in Akkus, Cookson and Horta¥ccsu (2016) and Uetake and Watanabe (2020). This paper proposes a new tractable method to estimate a endogenous joint venture/merger formation by extending the entry model developed by Seim (2006) and estimating the joint venture formation mechanism directly from the data. Our model and approach are applicable to broader situation, including endogenous mergers, and allows us to quantify the effect of joint ventures/mergers on entry incentive, incentive to form a joint venture, incentive to merge, and competition in the subsequent periods.

Broadly speaking, joint venture formation, the focus of this paper, can be seen as a particular type of joint bidding, which is studied by Cho, Jewell and Vohra (2002); Cantillon

(2008); Chatterjee, Mitra and Mukherjee (2017) and studied in some specific contexts of procurement auctions (Gugler, Weichselbaumer and Zulehner, 2021), subcontracting (Bouckaert and Van Moer, 2021) or patent auctions (Asker, Baccara and Lee, 2021).[2] The empirical literature on the joint bidding, including Iimi (2004); Estache and Iimi (2009); Branzoli and Decarolis (2015), develops slightly independently from the theoretical literature, i.e., the focuses of the literature is descriptively examining whether joint bidding indeed has pro-competitive effects or anti-competitive effects and find the pro-competitive effect of joint bidding. The notable exception is Gugler, Weichselbaumer and Zulehner (2021) that use a structural approach, endogenizing the entry and joint venture formation in a reduced-form way with heterogeneous bidders, and find the pro-competitive effects of joint bidding. Our paper complements Gugler, Weichselbaumer and Zulehner (2021) by explicitly modeling the joint venture formation and imposing equilibrium restrictions, which allows us to conduct a richer set of counterfactual analyses.

The final contribution of our paper is to the empirical works on the procurement auction. In particular, our modeling adds the joint venture formation process to the procurement auction models with endogeneous entry such as Li and Zheng (2009); Krasnokutskaya and Seim (2011). Their works demonstrate that the decision regarding endogenous *entry* is crucial for understanding the origins of efficiency in procurement auctions. Our paper additionally finds that the *choice of joint venture formation* also plays a decisive role in determining the efficiency of procurement auctions. Moreover, our empirical analysis focuses specifically on the scoring auction, which is categorized as multi-attribute auctions (Perrigne and Vuong, 2019). This type of auction incorporates non-monetary information to determine the winning bidder in procurement auctions, evaluating the quality of projects submitted by bidders to aim to long-term value maximization. Recent studies by Lewis and Bajari (2011); Kong, Perrigne and Vuong (2022) have empirically examined this auction format.[3]

[2]There is another strand of literature that investigates the joint bidding in the context of common value auctions where auctioneers sell natural resources such as petroleum. Although the theoretical papers, including Mead (1967) and Levin (2004), argue that the joint bidding function as a bidding rings or a collusion and hence impedes the competitive bids among the bidders, the empirical papers, including Millsaps and Ott (1985), Moody and Kruvant (1988), and Hendricks and Porter (1992), find the pro-competitive effects of joint bidding caused by pooling information, relaxing the budget constraint and risk sharing.

[3]There are other auction variants worth mentioning, such as the bid-preference or set aside policies, which aim to promote equity in procurement. Notable references in this regard include Corns and Schotter (1999);

We contribute to this literature by modelling a second stage as a scoring auction within a class of asymmetric auctions, which has not been considered in the literature yet.

2 Background and Motivating Facts

In this paper, we focus on the public procurement auctions held by five Regional Development Bureaus of the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT), which is the largest purchaser in Japan. We first provide the institutional background in Subsection 2.1, emphasizing the procedure of auctions and describing how we collect and construct the data. We then demonstrate some descriptive statistics, highlighting the difference between the bids of joint venture firms and the bids of non-joint venture firms (single bidders) in Subsection 2.2. One may concern collusive behavior of the Japanese construction firms, as pointed out by Kawai and Nakabayashi (2022*b*), Chassang et al. (2022), Kawai et al. (2022), Kawai and Nakabayashi (2022*a*) who establish some statistical evidence for collusion. We therefore test whether or not this concern applies to our data by employing a screening method proposed by Kawai and Nakabayashi (2022*b*) in Subsection 2.3.

2.1 Institutional Background and Data

This paper focuses on the public procurement auctions held by five Regional Development Bureaus of the MLIT. The main reason why we focus on these regional offices is controlling for auction rules; Though municipal and prefectural government offices also use procurement auctions, their auction rules are not perfectly coincide with each other. The main tasks of these regional offices are developing and maintaining the public infrastructures, including national routes, rivers, dams, ports and so on, under the direct control of the MLIT. Depending on these tasks, procurement of construction work is categorized into 22 types: Civil engineering, bridge building, pavement, landscaping and so on.[4]

A format of auctions used by each Regional Development Bureaus is a variant of first-

Marion (2007); Krasnokutskaya and Seim (2011); Athey, Coey and Levin (2013); Nakabayashi (2013); Rosa (2019).

[4]See Table 1 for the list of the categories.

price sealed-bid auction with secret reserved prices.[5] If a secret reserve price exceeds 100 million JPY in an auction, each procurer are strongly encouraged to use a scoring auction, explained in Subsection 2.3. Moreover, if a secret reserve price roughly exceeds 500 million JPY, each auction is now encouraged to invite joint ventures, aiming to generate some complementarities among the participating firms and taking advantages of scale economies. Though there are few exceptions for some gigantic construction work with short deadlines, the number of participating firms for each joint venture must be two or three firms, in principle. Furthermore, if a secret reserve price exceeds 680 million JPY, each procurement is now subject to the Agreement of Government Procurement, a multilateral agreement within the framework of World Trade Organization, implying that an equal treatment for the foreign firms must be guaranteed.[6]

Depending on the purposes, there are four types of joint ventures: (i) project-specific (Tokutei) joint ventures, (ii) fixed-term (Keijo) joint ventures, (iii) maintaining-regional-infrastructure-specific (Chiiki-iji) joint ventures, and (iv) restoration-projects-specific (Fukkyu-Fukkou) joint ventures. In this paper, we focus on the first type, which appears the most in the data.

We first collect the data from all 7 regional offices for all types of construction work between 2006 to 2022.[7] Procurement projects which involve joint ventures are mostly observed in auctions with reserve prices above 680 million JPY, as in Panel (A) of Table 1. Moreover, if we look at these 1,712 auctions, joint ventures are mostly appeared in two types of construction work—Civil Engineering and Bridge Building—and in five regions—Kanto, Hokuriku, Kinki, Shikoku, and Kyushu—as in Panel (B) and Panel (C) in Table 1. We therefore focus on the projects of civil engineering or bridge buidling with reserve prices above 680 million JPY, procured in Kanto, Hokuriku, Kinki, Shikoku, and Kyushu, which leaves 793 auctions out of 66,733.

[5]Secret reserved prices are unknown *ex ante* and the bidders whose bid exceed this secret reserved prices are disqualified.

[6]These threshold values are varied across municipal and prefectural governments and that is why we focus on the auctions held by each regional offices of the Japanese MLIT.

[7]There are 8 Regional Development Bureaus of MLIT include, Tohoku, Kanto, Hokuriku, Chubu, Kinki, Chugoku, Shikoku, and Kyushu. We exclude Tohoku area from our sample to remove the impact of the 2011 off the Pacific coast of Tohoku Earthquake. Note that there are several missing years for some regional development bureaus. See Appendix.

Table 1. Summary Statistics

	# of Auctions	# of JV Auctions	Rate of JV auction	Prob. JV winning	Log of Engineer's Estimate Mean	Min	Med	Max	# Bidders Mean	Min	Med	Max
Panel (A): By Reserve Prices												
Non WTO	66733	4	0.000	0.750	18.374	4.787	18.523	22.929	4.057	1	3	52
WTO	1712	245	0.143	0.408	21.025	16.097	20.885	24.350	10.411	1	10	35
Panel (B): By Construction Types												
Civil Engr.	806	120	0.149	0.475	21.284	18.081	21.161	24.350	11.428	1	10	35
PC	177	10	0.056	0.200	20.731	19.604	20.634	22.513	11.006	1	12	19
Bridge	460	97	0.211	0.381	20.919	19.524	20.807	22.782	11.311	1	12	24
machine	63	0	0.000	NaN	20.814	19.988	20.639	22.544	3.714	1	4	9
building	99	11	0.111	0.182	21.083	19.399	20.914	23.126	6.606	1	5	28
electricity	29	1	0.034	0.000	20.517	18.066	20.533	21.857	4.069	1	3	12
airconditioner	31	5	0.161	0.400	20.780	20.281	20.683	22.525	6.516	1	6	14
dredging	15	1	0.067	0.000	20.821	20.287	20.738	21.933	4.400	1	5	8
CC	7	0	0.000	NaN	20.209	19.837	20.041	20.610	9.143	4	11	14
management	18	0	0.000	NaN	17.518	16.097	17.118	20.609	2.833	1	2	8
bridgerepair	1	0	0.000	NaN	20.796	20.796	20.796	20.796	4.000	4	4	4
painting	1	0	0.000	NaN	17.824	17.824	17.824	17.824	2.000	2	2	2
slope	4	0	0.000	NaN	20.815	20.115	20.767	21.610	13.000	1	10.5	30
pavement	1	0	0.000	NaN	19.288	19.288	19.288	19.288	14.000	14	14	14
Panel (C): By Regions												
Kanto	637	130	0.204	0.462	21.181	20.102	21.044	24.350	9.722	1	9	33
Chubu	195	6	0.031	0.167	20.896	20.107	20.783	22.935	12.354	1	12	35
Hokuriku	68	13	0.191	0.462	20.955	16.519	20.906	23.598	10.529	1	11	32
Kinki	402	16	0.040	0.188	20.909	17.028	20.790	23.334	10.846	1	10	32
Chugoku	39	2	0.051	0.500	20.935	17.824	20.752	22.743	9.718	2	10	19
Shikoku	110	18	0.164	0.333	21.019	19.837	20.803	22.934	8.918	1	8.5	22
Kyushu	261	60	0.230	0.383	20.955	16.097	20.891	23.482	10.670	1	10	32
Final Sample	793	194	0.245	0.459	21.244	18.416	21.114	24.350	10.810	1	10	33

Notes. Rate of JV auctions is the rate of the number of the auctions in which at least one joint venture participate to the total number of auctions in each construction type. The second and the third panel is the detail about WTO type auctions.

2.2 Descriptive Statistics and Motivating Facts

In the auctions explained above, a bid submitted by each bidder–both single bidders and joint ventures–is weighted by "score," which is calculated by the combination of the bidder attributes and the characteristics of the procurement project, based on the pre-determined scoring rules.[8] The auctioneers then compare the "effective bids," defined as the ratio of the score to the submitted bid, i.e., $\frac{s_i}{b_i} \times 10^8$ where b_i and s_i denote a bid and a score of bidder i.[9] A bidder with the highest effective bid wins the auction, implying that submitting the lower bid or obtaining higher score increase the likelihood of winning. The minimum score is 100, whereas the maximum score are varied by auctions, depending on difficulties and complexities of projects, which can be 200 at maximum. The effective bids are therefore typically ranged from 0 to 200.

[8] For joint ventures, we observe a score for a joint venture, not for individual firms.

[9] In our data, the bids are typically in order of 10^8 JPY, implying that $\frac{s_i}{b_i}$ become tiny values. Therefore, in the data, effective bids are defined as $B_i \equiv \frac{s_i}{b_i} \times 10^8$.

In principle, score is not perfectly known to the bidders when submitting their bids, because the scoring rule may contain some parts that involve uncertainty, as well as some deterministic parts based on the bidders' attributes. However, in our model, we assume that bidders decide their bids, knowing their score. There are several justifications for our assumption. First, 15 years have passed since the Japanese government introduced this scoring rules and it is reasonable to believe that the firms are now able to form an appropriate expectation of their score in advance.[10] Second, the data also support our assumption. Table 2 summarizes the results where we regress the logarithm of submitted bids on the score and some other variables, as well as some fixed effects. We find the statistically significant positive correlation between the submitted bids and the score, implying that their bids reflect their scores and this results could not happen when bidders did not know their scores.

Figure 1 depicts the distributions of firm-level behavior in our sample: logarithm of effective bid ($\ln B_i$), logarithm of bid ($\ln b_i$), and score (s_i). The blue bins represent the joint ventures, and orange bins represent the single bidders. The left column shows the histograms of the three variables observed in all the auctions, while the right column is about the bids observed in the auctions in which at least one joint venture exists. While we see the small effective bids by joint ventures in Panel (a), Panel (b) shows this is due to selective entry. From Panel (c), we know that joint ventures enter the relatively expensive projects even when we focus on WTO type auctions. As to the score, the single bidders and the joint ventures face the similar distributions and we do not find the systematic difference about the auctions in which at least one joint venture exists.

2.3 Collusion in Our Data

Before proceeding to our main analysis, we check whether the bidding patterns observed in our data exhibit any symptoms of collusion. This is because it is well known that collusive behaviors are suspected in the Japanese procurement auction (e.g. Kawai and Nakabayashi,

[10] One evidence of this information structure is provided in Kawai and Nakabayashi (2022*b*). They argue that the some firms in the scoring auction of Japanese procurement conduct bid rotations based on the level of the score: after one firm with the high score wins an auction, another firm with the lower score takes turn to win an auction. Such behaviors should not be observed when the firms did not know their scores in advance.

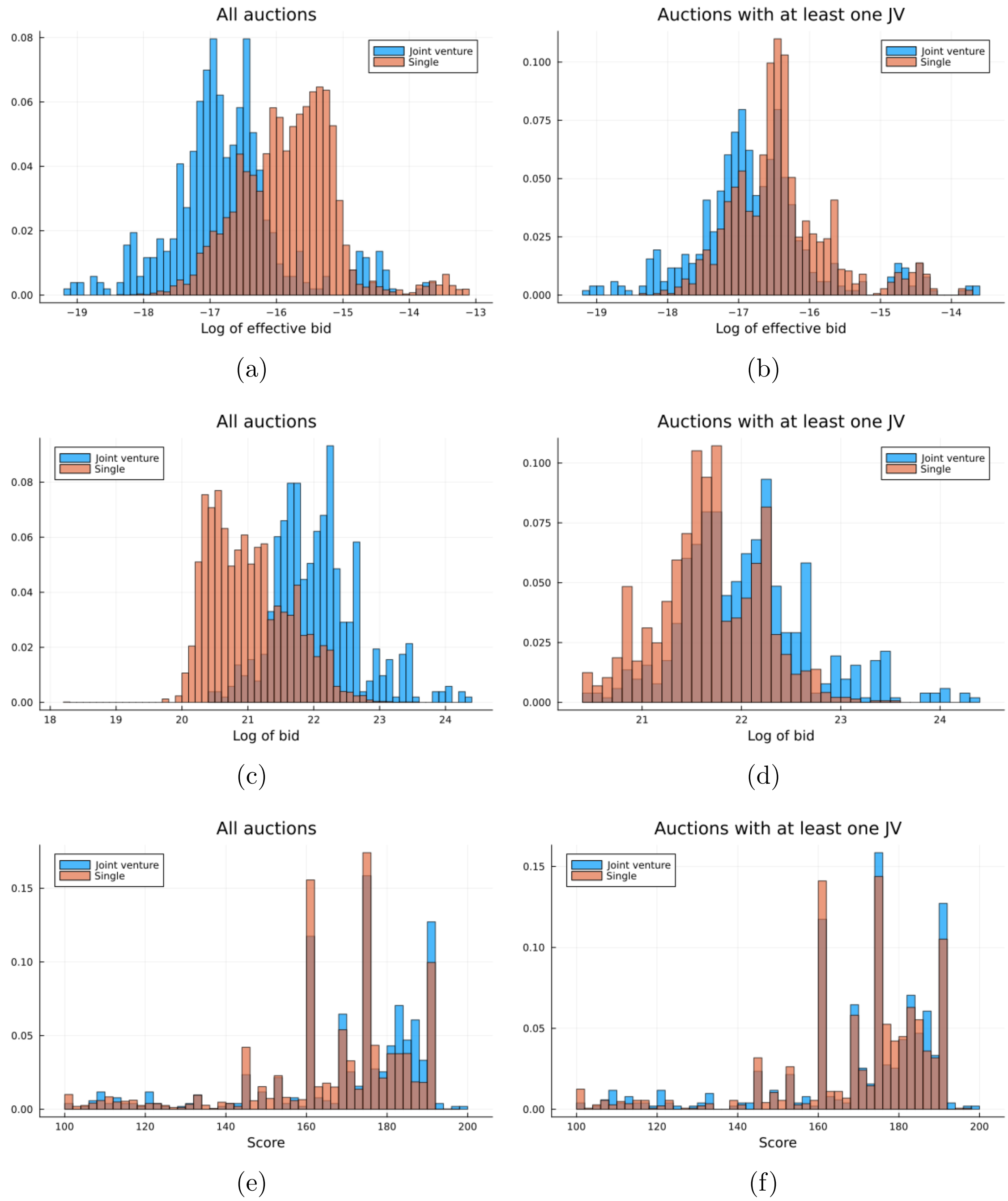


Figure 1. Histograms of effective bids, log of bids, and entrants' scores. Blue bins represent joint ventures, and red bins represent single bidders. In the left column, we use all the auctions. In the right column, we use the auctions in which at least one joint venture participates. The first row is about the log of effective bids, defined as the score's ratio to the bid. The second row is about the log of bids, and the third row is about the score.

Table 2. Regression Results

	(1) ln(bid)	(2) ln(bid)	(3) ln(bid)
Score	0.003***	0.001**	0.002***
	(0.000)	(0.000)	(0.001)
# bidders		-0.021***	-0.004
		(0.001)	(0.008)
Score × # bidders			-0.000**
			(0.000)
Constant	20.537***	20.636***	20.403***
	(0.060)	(0.072)	(0.129)
Year FE		√	√
Region FE		√	√
Type FE		√	√
N	8572	8572	8572
R^2	0.010	0.172	0.173

Notes: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

2022*b*; Chassang et al., 2022; Kawai et al., 2022; Kawai and Nakabayashi, 2022*a*) and, if the firms indeed engage in collusion, our model/empirical strategy may not work in the subsequent sections. We therefore examine our data with a screening method proposed by Kawai and Nakabayashi (2022*b*) and show that our data do not indicate any suspicious bidding behaviors.

Following Kawai and Nakabayashi (2022*b*), we first split our data by region and year and then apply their screening method to each subset of our data to identify the sets of auction which may suffer from collusion.[11] The results are graphically demonstrated in Figure A1 and Figure A2[12]. We do not find any suspicious bidding patterns in our data, unlike Kawai and Nakabayashi (2022*b*). This discrepancy between their results and our results is likely to come from the difference between the type of the procurements; We focus on relatively

[11]Their screening method is based on the fact that (we need briefly summarize Kawai and Nakabayashi - below is just a copy and paste from IKegami-kun) It uses the mathematical fact that, when we focus on the marginally losing and winning bidders, the winner is determined at random if they do not form a collusion. If the auction suffers from any collusive behavior, the submitted bid of the marginally loser unnaturally differs from the winning bid: for example, when the firm with the higher technology tries to loose the auction, the submitted bid must be unnaturally higher. By checking this gap, we can detect the collusive bids. As the example of Nippo cooperation in Kawai and Nakabayashi (2022*b*), this method can be applied to each firm and we find the set of suspicious firms.

[12]If we detect a jump at the point of 0 in the figures, this implies that the high quality bidders, who are likely to win, do carefully choose their bids to lose the auction. This is one evidence of the collusion.

large-scale auctions compared with the auctions studied in the existing literature and the bidders in our data would face much stricter compliance requirements. We therefore keep all observations described in the previous subsection for our main analysis.

3 Model

We consider a two-stage model. In the first stage, *entry and joint venture formation stage*, the potential entrants express their intentions regarding the entry type: to try to form a joint venture, to enter as a single bidder, or to stay out from the market. Then, the set of the intentions of the potential entrants leads to a distribution over the outcome, the number of joint ventures and the number of single bidders. In the second stage, *bidding stage*, the realized entrants (realized in the first stage) compete in the scoring auction. Note that there are two types of entrants: joint venture and single bidder. We treat them as a asymmetric entrants and we build the model as an asymmetric scoring auction. In the following, we describe the details of the two stages in a reverse order.

3.1 Bidding stage model

In this section, we use the followings notations: given an auction, i denotes the index of the entrants in the auction, s_i denotes the score of the firm i, b_i denotes the submitted bid of the firm i, and the effective bid is defined as $B_i \equiv \frac{s_i}{b_i}$. The auction is a scoring auction, where the bidder who submits the lowest effective bid wins the auction. The engineer's estimate of the project cost is denoted by p.

When the entrant i wins the auction, the payoff is given by

$$b_i - \tilde{c}_i p = \frac{s_i}{B_i} - \tilde{c}_i p,$$

where $\tilde{c}_i$ is the individual cost factor normalized by p, and the actual cost of the entrant i is equal to $\tilde{c}_i p$. We assume that the score and the individual cost factor are private information. We observe p, b_i and s_i while the individual cost factor $\tilde{c}_{ij}$ is not observed.

The number of the joint ventures is denoted by M, and the number of single bidders is denoted by N. In a slight abuse of notation, M and N also represent the sets of each type of bidders. First, we describe the optimization problem for a single bidder i as

$$\max_{B} \; Pr\left(\left\{B_j^{JV} \leq B \;\forall j \in M\right\},\; \left\{B_j^S \leq B \;\forall j \in N \setminus \{i\}\right\}\right)\left(\frac{s_i}{B} - \tilde{c}_i p\right),$$

where we denote the effective bid of a single bidder, B_j^S, and a joint venture, B_j^{JV}, by capital letters. By taking the logarithm of the effective bids, we have the following equivalent problem:

$$\max_{B} \; Pr\left(\left\{\ln B_j^{JV} \leq \ln B \;\forall j \in M\right\},\; \left\{\ln B_j^S \leq \ln B \;\forall j \in N \setminus \{i\}\right\}\right)\left(\frac{s_i}{B} - \tilde{c}_i p\right).$$

We can define the problem for a joint venture in the similar manner just by replacing M by $M \setminus \{i\}$ and $N \setminus \{i\}$ by N.

For each type of the entrant, we assume that the pair of the score and the individual cost factor is drawn independently from an identical distribution.

Assumption 1. *If the entrant i s a single bidder, the pair of the score and the individual cost factor, $(s_i, \tilde{c}_i)$, is drawn independently from G^S. If i is a joint venture, $(s_i, \tilde{c}_i)$, is drawn independently from G^{JV}. And we denote the distribution of $\frac{\tilde{c}_i}{s_i}$ of single bidders and the same of joint ventures by $\tilde{G}^S$ and $\tilde{G}^{JV}$.*

Under this assumption and given M and N, and assuming that this auction has a unique equilibrium, the logarithm of the effective bids of single bidders and joint ventures follow two distinct distributions independently in the equilibrium. We denote them by F^S and F^{JV}. Then the payoff maximization problem of a single bidder i is written as follows:

$$\max_{B} \; F^S(\ln B)^{N-1} F^{JV}(\ln B)^M \left(\frac{s_i}{B} - \tilde{c}_i p\right). \tag{1}$$

We write the maximized expected payoff by $V^S(\frac{\tilde{c}_i}{s_i}; M, N, p)$ and the same one for joint venture by $V^{JV}(\frac{\tilde{c}_i}{s_i}; M, N, p)$.

3.1.1 Equilibrium

Here, we discuss the existence and the uniqueness of the equilibrium in this auction according to the argument of Lebrun (1999), which argues the existence and the uniqueness of the Bayesian Nash equilibrium in the first price asymmetric auction. Though our model are different from its setting in several aspects, we can still apply the similar argument to prove the existence and uniqueness of the equilibrium.

First, we take the first order condition of the problem (1) given the distributions of the logarithm of the effective bids to characterize the bidding strategy. For a single bidder and for a joint venture, the FOC's are the following:

$$\begin{cases} 1 - \frac{\tilde{c}_i}{s_i} pB = \frac{1}{(N-1)\frac{f^S(\ln B)}{F^S(\ln B)} + M\frac{f^{JV}(\ln B)}{F^{JV}(\ln B)}}, \\ 1 - \frac{\tilde{c}_i}{s_i} pB = \frac{1}{N\frac{f^S(\ln B)}{F^S(\ln B)} + (M-1)\frac{f^{JV}(\ln B)}{F^{JV}(\ln B)}}. \end{cases} \tag{2}$$

The optimal effective bid depends on the private information only through $\frac{\tilde{c}_i}{s_i}$. Hence, given the number of entrants of both types and the expected cost, we can solve the above two conditions and get the optimal bidding strategies $B_S\left(\cdot\,; F^S, F^{JV}\right)$ and $B_{JV}\left(\cdot\,; F^S, F^{JV}\right)$ that map $\frac{\tilde{c}_i}{s_i}$ to the effective bid. In other words, although our problem has two dimensional private information, the optimization problem is reduced to a one-dimensional problem. We define an equilibrium in this game as follows.

Definition 1. *The pair of two invertible functions mapping $\frac{\tilde{c}}{s}$ to an effective bid, $B_S^\star(\cdot)$ and $B_{JV}^\star(\cdot)$, is an equilibrium, if it satisfies*

$$\begin{cases} B_S^\star(\cdot) = B_S\left(\cdot\,; F^S, F^{JV}\right) \\ B_{JV}^\star(\cdot) = B_{JV}\left(\cdot\,; F^S, F^{JV}\right) \end{cases} \tag{3}$$

where

$$\begin{cases} F^S(\ln B) \equiv Pr\left(B_S^\star\left(\frac{\tilde{c}_i}{s_i}\right) \le B\right) \\ F^{JV}(\ln B) \equiv Pr\left(B_{JV}^\star\left(\frac{\tilde{c}_i}{s_i}\right) \le B\right). \end{cases}$$

Now, assume that there is an equilibrium in this game and the bidding strategy is decreasing in $\frac{\tilde{c}_i}{s_i}$. This means that when the firm faces a higher cost or the score is lower, i.e., the firm is more competitive, the firm submits lower effective bids. If the bidding strategy is increasing in $\frac{\tilde{c}_i}{s_i}$, the reverse is true; then each entrant has an incentive to deviate to submitting more competitive bids. Hence it is not restrictive that we assume the bidding strategy is decreasing in $\frac{\tilde{c}_i}{s_i}$. Under an equilibrium, the problem (1) is transformed into the following:

$$\max_{B} \left(1 - \tilde{G}^S\left(B_S^{\star,-1}(B)\right)\right)^{N-1}\left(1 - \tilde{G}^{JV}\left(B_{JV}^{\star,-1}(B)\right)\right)^{M}\left(\frac{s_i}{B} - \tilde{c}_i p\right).$$

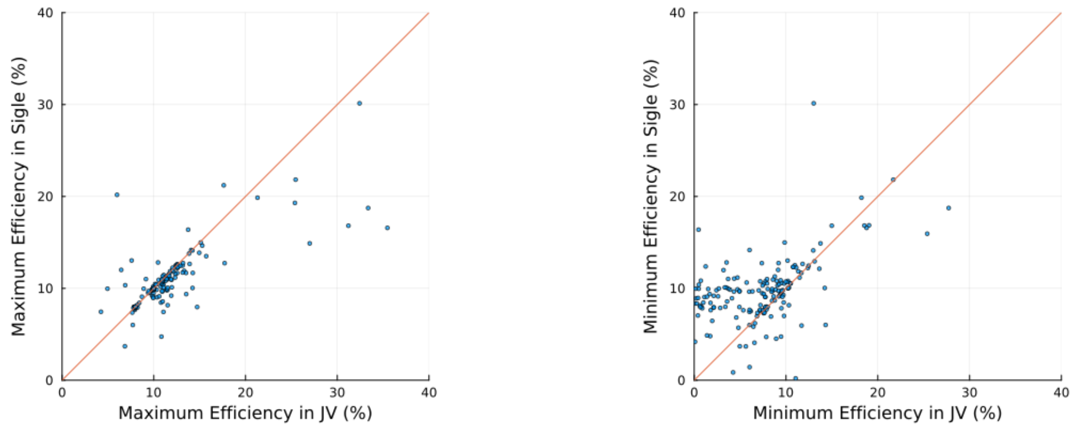
Here, we use the fact that $B_S^\star(\cdot)$ and $B_{JV}^\star(\cdot)$ are decreasing. We have an analogous problem for a joint venture. By taking the first order conditions for both types and solving the system of differential equations, we have the following two differential equations:

$$\begin{cases} \frac{d}{dB}B_{JV}^{\star,-1}(B) = \frac{1}{N+M-1}\frac{1-\tilde{G}^{JV}\left(B_{JV}^{\star,-1}(B)\right)}{\tilde{g}^{JV}\left(B_{JV}^{\star,-1}(B)\right)}\frac{1}{B}\frac{1}{B_{JV}^{\star,-1}(B)Bp-1}, \\ \frac{d}{dB}B_{S}^{\star,-1}(B) = \frac{1}{N+M-1}\frac{1-\tilde{G}^{S}\left(B_{S}^{\star,-1}(B)\right)}{\tilde{g}^{S}\left(B_{S}^{\star,-1}(B)\right)}\frac{1}{B}\frac{1}{B_{S}^{\star,-1}(B)Bp-1}. \end{cases}$$

Note that the right hand side is continuous in B over $[0, \frac{s_i}{\tilde{c}_i p}]$ for each i in both equations. We assume that the right hand side is Lipschitz continuous w.r.t. $B_{JV}^{\star,-1}(B)$ in the first equation and $B_S^{\star,-1}(B)$ in the second equation.

Assumption 2. $\frac{1-\tilde{G}^{JV}(\alpha)}{\tilde{g}^{JV}(\alpha)}\frac{1}{\alpha Bp-1}$ *and* $\frac{1-\tilde{G}^{S}(\alpha)}{\tilde{g}^{S}(\alpha)}\frac{1}{\alpha Bp-1}$ *are Lipschitz continuous w.r.t.* α.

Then there is a solution to the differential equation of each type and that is unique given an initial condition. This implies that the equilibrium of this auction is unique up to the initial condition if there is at least one equilibrium. Note that no firm bids the bid bigger than the cost: for every entrant i, we have $b_i > \tilde{c}_i p \Leftrightarrow \frac{\tilde{c}_i}{s_i}pB_i - 1 < 0$. This implies that $\frac{d}{dB}B_{JV}^{\star,-1}(B)$ and $\frac{d}{dB}B_S^{\star,-1}(B)$ are negative, which does not contradict with our assumption as $B_{JV}^\star(\cdot)$ and $B_S^\star(\cdot)$ are decreasing.



(a) Maximum of efficiency

(b) Minimum of efficiency

Figure 2. Comparison between single bidder and joint venture with respect to the submitted bids.

3.1.2 Ex-ante expected payoff

To analyze the incentive in the entry and joint venture formation stage, we define the ex ante expected payoffs that the potential entrant faces before his entry. As in Levin and Smith (1994), we assume that the potential entrants do not know his own cost score ratio before the entry. This assumption on the information structure is reasonable and standard in the literature because appropriate assessment on the project cost and score rating requires certain effort and potential entrants need to decide whether to put such effort or not in the first place, which we view as the entry decision. Furthermore, for the score, the potential entrants do not know the detail formula in advance. All they know is which characteristics the government takes into account and the maximum points.

This model is justified by our data. Now we measure bid efficiency for each bidder in each auction by comparing the engineer's estimate to the submitted bid:

$$\text{efficiency} = \frac{\text{Engineer's estimate} - \text{Submitted bid}}{\text{Engineer's estimate}} \times 100.$$

Figure 2 compares the maximum and the minimum of the efficiencies within the single bidders and the joint ventures. Panel (a) indicates that the joint venture is likely to bid the lower price: there seem to exist cost synergy. However, as shown in Panel (b), this competitiveness of the joint venture does not always realize: the minimum efficiency of the joint ventures is relatively larger than those of the single bidders. In other words, the joint ventures can be very weak in the scoring auction. We interpret Figure 2 as the evidence that the cost information in the second stage is not known to the potential bidders in the first stage. This assumption greatly simplifies our formulation of the first stage. Hereafter, in the model of the entry and joint venture formation, we assume that the distributions of the individual cost and the score for the single bidder and the joint venture are all they know in the first stage.

We define the ex ante expected payoff *conditional on* the realized entry pattern for each pair of (M, N, p) and the type of the entrant, and we denoted them by $u_{JV}(M, N; p)$ and $u_S(M, N; p)$ where the lower script represents the type of the entrant, joint venture and single bidder.

$$\begin{cases} u_{JV}(M, N; p) = E_{\frac{\tilde{c}_i}{s_i}} \left[V^{JV}(\frac{\tilde{c}_i}{s_i}; M, N, p) \right], \\ u_S(M, N; p) = E_{\frac{\tilde{c}_i}{s_i}} \left[V^{S}(\frac{\tilde{c}_i}{s_i}; M, N, p) \right]. \end{cases}$$

The expectations are taken with respect to the realization of the fraction $\frac{\tilde{c}_i}{s_i}$. Note that we consider the functions u_{JV} and u_S as the ex ante expected payoffs. Each value of this function corresponds to the ex ante expected payoff conditional on the entry pattern (M, N) and the engineer's estimate p.

When potential entrants make their entry decision, however, they do not know the realization of M and N yet. Given an engineer's estimate p, to compute the *unconditional* ex ante expected payoff, they need to take an expectation of these u_{JV} and u_S with some probability distribution over the entry outcome. In the following section, we describe the intention choice problem in the entry and joint venture formation stage, and describe the probability distribution as the outcome of potential entrants' strategy.

3.2 Entry and joint venture formation stage

The goal of this section is to characterize the distribution over the entry patterns. Let us emphasize that our model does not predict the realization and identity of entrant, joint ventures and single bidders. Instead, our model predicts the distribution over the realization of the number of joint ventures and single bidders. In this sense, we assume homogeneous potential entrants. In the particular context of procurement auctions, this observational homogeneity is justifiable because the auctioneer (government) set the the entry criterion that all the potential entrants must satisfy, which makes the potential entrants similar in observables. For example, the project like a bridge building puts the minimum requirement about the size and the technology of the potential entrants to guarantee that the project is successfully executed regardless of the auction result.

We parameterize the distribution over the outcomes by three types of parameters: the entry cost as a joint venture , $c_{JV} \in \mathbb{R}$, the entry cost as a single bidder, $c_S \in \mathbb{R}$, and a set of outcome mixing matrices $R = \left(R^{JV}, R^S, R^N\right)$. Hereafter, first I describe the role of outcome mixing matrices in our model and then characterize the equilibrium of our model.

3.2.1 Outcome mixing matrix

In our model, the observationally homogeneous potential entrants first express their intentions about the mode of entry. There are three intentions: JV, S, and N. When the firm wants to form a joint venture with the other firms, the firm chooses JV. Note that, even after expressing this intention, the firm might not be able to form a joint venture because it requires at least one another firm who wants to form a joint venture and the compatibility with the other firms also matters to form a joint venture. In this sense, we call this choice as an intention. We assume that when the firm chooses S, the firm enters as a single bidder in the auction[13]. When the firm chooses N, the firm stays out of the market. Note that S and N directly leads to the entry type in contrast to the case of JV. We denote the number of firms expressing each intention by L_1, L_2 and L_3 and call the triplet (L_1, L_2, L_3) by *intention pattern*. When we have the finite number of potential entrants, the total number of intention patterns is finite, which is denoted by J.

For each firm, the possible entry realization is composed of the number of joint ventures and the number of single bidders and the indicator of the entry type. We call the pair of the number of joint ventures and the number of single bidders by entry pattern (M, N)

[13]This is just an option. Our model can allow the possibility that the potential entrant does not enter or form a joint venture even after it chooses S as its intention.

and denote the indicator by $\delta \in \{JV, S, N\}$. From the potential entrant's point of view, an outcome is a triplet of (M, N, δ). We assume M and N has a upper bound, $\bar{M}$ and $\bar{N}$, respectively. Therefore, the total number of outcomes is finite; The total number of entry patterns is denoted by $K = (\bar{M}+1)(\bar{N}+1)$ where $+1$ is necessary to express the case of no entry and the total number of outcomes is $3K$. With slight loss of generality, let us assume $\bar{N}$ to be equal to the number of potential entrants. Then, we will have $J =_{\bar{N}+2} C_2$.

Next, we describe the correspondence between the intention and realization of outcome. There are two different approaches: (1) specifying the coalition formation process and applying a "reasonable" solution concept, or (2) leaving it unspecified and directly inferring the correspondence directly from the data. Since there is no "standard" model in coalition formation with externality and researchers cannot observe the actual process, we take the second approach. Namely, Given an intention pattern (L_1, L_2, L_3) and one intention $I \in \{JV, S, N\}$, we assume an outcome (M, N, δ) realizes with probability $r(M, N, \delta \mid L_1, L_2, L_3; I)$, e.g., $r(M, N, JV \mid L_1, L_2, L_3; JV)$ is the probability that M joint ventures enter and N single bidders enter and the firm can form a joint venture when the total numbers of firms choosing $JV/S/N$ are $L_1/L_2/L_3$ and he chooses JV. We naturally assume that the intention of S and N determines the entry type directly, i.e., $r(M, N, JV \mid L_1, L_2, L_3; S) = r(M, N, N \mid L_1, L_2, L_3; S) = r(M, N, JV \mid L_1, L_2, L_3; N) = r(M, N, S \mid L_1, L_2, L_3; N) = 0$ for all the pairs of (M, N), and $\sum_{(M,N)} r(M, N, S \mid L_1, L_2, L_3; S) = 1$ for all (L_1, L_2, L_3) with $L_2 \geq 1$.

By collecting these probabilities, we make a probability vector for (L_1, L_2, L_3). And by stacking these columns row-wisely, we make up R^I. In other words, R^I is a $3K \times J$ column stochastic matrix jth column is the probability vector over the outcomes for jth intention pattern. We can make up R^I for each intention $\{JV, S, N\}$. Each of these are called an outcome mixing matrix.

Let us provide an example of a outcome mixing matrix. Suppose there is a deterministic link between L_1 and M, such as all potential entrants expressing the intent to form a JV get matched with someone else randomly and $\lfloor \frac{L_1}{2} \rfloor$ JVs are formed (if L_1 is a even number, $\frac{L_1}{2}$ pairs are formed and if L_1 is a odd number, $\lfloor \frac{L_1}{2} \rfloor - 1$ pairs are formed and one trio is formed). Under this coalition formation process, $r(\lfloor \frac{L_1}{2} \rfloor, L_2, JV; L_1, L_2, L_3; JV) = r(\lfloor \frac{L_1}{2} \rfloor, L_2, S; L_1, L_2, L_3; S) = 1$.

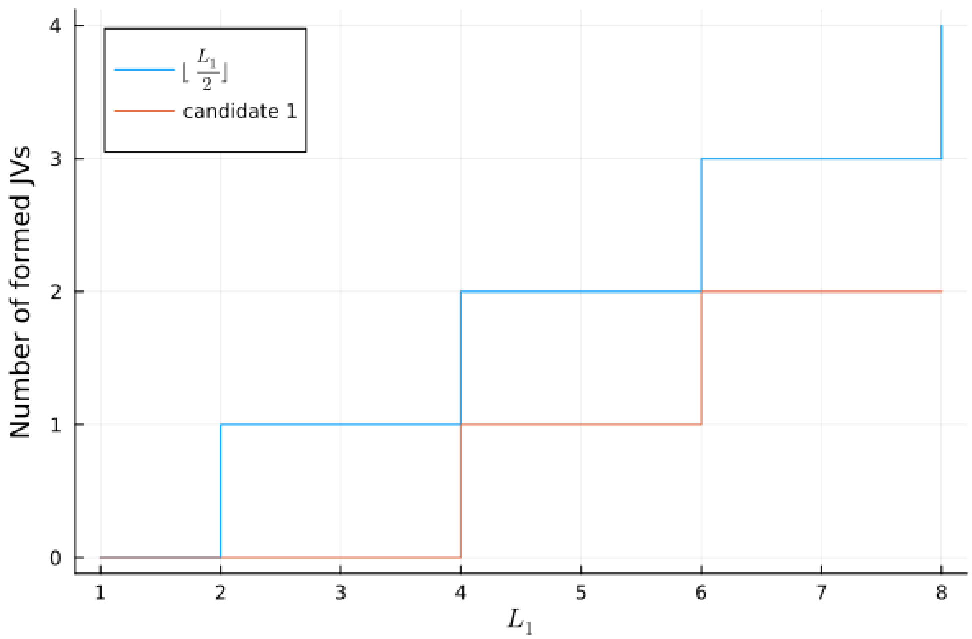


Figure 3. The illustration of feasible Φ. The orange line is one example of feasible Φ. The blue line is the upper bound for any feasible Φ. This upper bound is obtained by $\lfloor \frac{L_1}{2} \rfloor$.

Even though we do not specify the coalition formation process, assuming a deterministic relationship between L_1 and M drastically reduce the number of parameters in our model and improve the quality and reliability of estimation. Hence, we assume there is that there is a mapping $\Phi : \mathbb{N} \to \mathbb{N}$ from the number of potential entrants choosing JV as his intention to the number of successfully formed joint ventures.

The nice property of this type of outcome mixing matrix is that the number of feasible Φ is finite. We say Φ is *feasible* when Φ has no jump of size two or more and is below $\lfloor \frac{L_1}{2} \rfloor$, which is the upper bound for the number of the formed joint ventures because it requires at least two firms to form a joint venture. Suppose there are 8 potential entrants. The orange line in Figure 3 is one example of feasible Φ. Under this Φ, even when 5 firms choose JV as their intentions, only one joint venture is successfully formed. Note that, in this example of R, we do not restrict the number of firms to form a joint venture, i.e., we allow three or more firms form a joint venture. Also, we do not impose $\Phi(N) = \lfloor \frac{N}{2} \rfloor$ because there may be friction in JV formation, i.e., not all potential entrants interested in JV cannot form a JV, and/or more than two potential entrants may form a JV. The total number of such functions is finite for any number of potential entrants and so we can collect all the functions. Even under with a deterministic mapping $\Phi(N)$, the realization of (M, N) is still random given (L_1, L_2, L_3). This is because we do not specify how potential entrants behave when they failed to form a JV; they may enter as a single bidder or stay out.

3.2.2 Equilibrium

Here we define the Bayesian Nash equilibrium in the entry and joint venture formation stage given one set of outcome mixing matrices $R = \left(R^{JV}, R^S, R^N\right)$. First, we introduce a probability vector P with length of $3K$ which is the prediction over the outcomes for each intention. The elements from 1 to K The elements from the first to Kth of P are the probabilities over the entry patterns given the firm can form a joint venture. The next K elements are the probabilities over the entry patterns given the firm enters as a single bidder. And the last K elements of P are the the probabilities over the entry patterns given the firm does not enter.

Using this prediction P and entry costs, the potential entrant computes the expected payoff attached to each intention:

$$\begin{cases} v_{JV}(P^{JV}) = \left(P^{JV}_{1:K} \cdot u_{JV} - c_{JV}\right) + \left(P^{JV}_{K+1:2K} \cdot u_S - c_S\right) + \left(P^{JV}_{2K+1:3K} \cdot 0\right) \\ v_S(P^S) = \left(P^S_{K+1:2K} \cdot u_S - c_S\right) \\ v_N(P^N) = P^N_{2K+1:3K} \cdot 0 \end{cases}$$

where the upper script of P represents the chosen intention. Hereafter we use $P = (P^{JV}, P^S, P^N)$. u_{JV} and u_S is the vector containing the ex ante expected payoffs of each entry type. By this formulation, we interpret c_{JV} as the entry cost as joint venture, which includes the management cost necessary to decide the bid in the auction as a joint venture or any frictional cost associated with forming a joint venture. By comparing with the entry cost as a single bidder, c_S, the additional execution cost incurred by forming and managing a joint venture is computed by $c_{JV} - c_S$. Note that we normalize the benefit of staying out to 0.

The potential entrants face a discrete choice problem among the three intentions $\{JV, S, N\}$. We include the additive disturbance term $\epsilon_i = (\epsilon_i(JV), \epsilon_i(S), \epsilon_i(N))$ as the unobserved cost in their decision problem. We assume that ϵ_i follows a Type I extreme value distribution.

The choice probabilities are written as follows:

$$\begin{cases} m(JV;P) = \frac{e^{v_{JV}(P^{JV})}}{e^{v_{JV}(P^{JV})}+e^{v_S(P^S)}+e^{v_N(P^N)}} \\ m(S;P) = \frac{e^{v_S(P^S)}}{e^{v_{JV}(P^{JV})}+e^{v_S(P^S)}+e^{v_N(P^N)}} \\ m(N;P) = \frac{e^{v_N(P^N)}}{e^{v_{JV}(P^{JV})}+e^{v_S(P^S)}+e^{v_N(P^N)}} \end{cases}.$$

We write $m(P)$ as the triplet of the choice probabilities given one prediction triplet P. Then we have the distribution over the intention patterns which is denoted by $Q(m(P))$, which is the multinomial distribution of the probability vector is $m(P)$ and the total number of trials is $\bar{N}-1$[14]. Now we can express the distribution over the outcomes by the mixture of the distributions in each intention pattern using outcome mixing matrices: for the firm who chooses JV, the distributions over the outcomes can be expressed by

$$R^{JV}Q(m(P)).$$

Also for the firms who choose S or N, we have the similar expressions: $R^S Q(m(P))$ and $R^N Q(m(P))$.

As in the definition of the Bayesian Nash equilibrium in Seim (2006), we characterize the equilibrium of this game by the prediction $P^\star$ which is equal to the realized distributions over the outcomes. In other words, $P^\star$ solves the following fixed point problem is the equilibrium prediction of our model:

$$\begin{cases} P^{\star,JV} = R^{JV}Q(m(P^\star)) \\ P^{\star,S} = R^S Q(m(P^\star)) \\ P^{\star,N} = R^N Q(m(P^\star)). \end{cases}$$

This is equivalent to

$$P^\star = RQ(m(P^\star)) \tag{4}$$

[14] Because we fix the intention of one firm, we have to consider the distribution of the intentions of the other potential entrants.

where R is the stack of R^{JV}, R^{S}, R^{N}.

By Proposition 1, we know that $RQ(m(P))$ is a contraction mapping. This implies that the equilibrium level of prediction $P^{\star}$ is unique in our model.

Proposition 1. *$RQ(m(P))$ is a contraction mapping w.r.t. P.*

Proof. See Appendix. □

Finally, we can compute the distribution over the entry patterns based on $P^{\star}$. First we compute the marginal distributions over the entry patterns for each intention and then compute the weighted average of the marginal distributions. We denote this equilibrium distributions over the entry patterns by $g(M, N)$.

Remark 1. *The studies about coalition formation, see Ray and Vohra (2015) for a survey, have proposed a lot of models to describe how groups are formed. In their framework, we can analyze even the group formation under externality. However, the outcome of the model heavily depends on the assumption about the farsightedness of the players, like in the example 5.5. in Ray and Vohra (2015), and on the protocol which specifies the process of the group formation such as the order of the group formation proposer. For an empirical work about the group formation in the procurement auction, we need a model which avoids these specifications, because we do not know the exact process of the joint venture formation. This is why we do not adopt the models in the coalition formation.*

4 Estimation

In this section, we describe the estimation strategies for the two stages separately. In the bidding stage, the estimation target is the distributions of the pair $(\tilde{c}_i, s_i)$ of a joint venture and a single bidder. This is achieved by retrieving the individual cost factor $\tilde{c}_i$ from the first order condition. Given the estimated distributions, we then estimate the ex-ante expected payoffs, u_{JV}, u_S, for the different levels of the expected cost. In the entry stage, we use the expected ex-ante payoffs to estimate the entry cost of a joint venture and a single bidder and the outcome mixing matrices.

4.1 Estimation of bidding sage

Hereafter, we denote the index of auction by the subscript j. From equation (2), we have the following inversions for the cost of both types:

$$\tilde{c}_{ij} = \frac{s_{ij}}{p_j B_{ij}} \left(1 - \frac{1}{(N_j - 1)\frac{f^S(\ln B_{ij})}{F^S(\ln B_{ij})} + M_j \frac{f^{JV}(\ln B_{ij})}{F^{JV}(\ln B_{ij})}} \right) \tag{5}$$

for a single bidder, and

$$\tilde{c}_{ij} = \frac{s_{ij}}{p_j B_{ij}} \left(1 - \frac{1}{N_j \frac{f^S(\ln B_{ij})}{F^S(\ln B_{ij})} + (M_j - 1) \frac{f^{JV}(\ln B_{ij})}{F^{JV}(\ln B_{ij})}} \right) \tag{6}$$

for a joint venture. Once we estimate the two distributions of the effective bids for a single bidder and a joint venture, we can retrieve the individual cost factor for each firm using the above equation using these equations.

Now we describe the estimation procedure for the distributions of the effective bids. Note that the optimization problem implies that the optimal level of effective bid is dependent on the combination of (p, M, N) and whether or not the firm is a single bidder or a JV. First we assume that the logarithm of the effective bids follow a Normal distribution.

Assumption 3.

$$\ln B_{ij}^{JV} \sim N\left(\theta_j^{JV}, \sigma_j^{2,JV}\right), \ \ln B_{ij}^{S} \sim N\left(\theta_j^{S}, \sigma_j^{2,S}\right)$$

We estimate these distributions by sieve methods, i.e., we estimate the mean and the variance using the following regerssion:

$$\ln B_{ij} = poly(d_{ij}^{JV}, p_j, M_j, N_j; \beta) + \epsilon_{ij}.$$

where d_{ij}^{JV} is the dummy variable for the joint venture and $poly(X, \beta)$ represents the polynomial function of the variables X with some degree when the coefficients are β. Using all the data, run the above regression and denote the estimated coefficients by $\hat{\beta}$. Given this result, the estimated distributions in auction j are as follows:

$$\ln B_j^{JV} \ \sim \ N\left(poly(d_{ij}^{JV}=1, p_j, M_j, N_j; \hat{\beta}),\ \hat{\sigma}^{2,JV}\right), and$$

$$\ln B_j^{S} \ \sim \ N\left(poly(d_{ij}^{JV}=0, p_j, M_j, N_j; \hat{\beta}),\ \hat{\sigma}^{2,S}\right).$$

where the estimated variances are

$$\hat{\sigma}^{2,JV} = \frac{1}{\#JV}\sum_{ij:d_{ij}^{JV}=1}\left(\ln B_{ij} - poly(d_{ij}^{JV}=1, p_j, M_j, N_j; \hat{\beta})\right)^2, and$$

$$\hat{\sigma}^{2,S} = \frac{1}{\#Single}\sum_{ij:d_{ij}^{JV}=0}\left(\ln B_{ij} - poly(d_{ij}^{JV}=0, p_j, M_j, N_j; \hat{\beta})\right)^2.$$

Based on the estimated distributions, we retrieve the individual cost factors by the equation (5) and (6).

4.1.1 Computation of ex-ante expected payoffs

We compute the ex-ante expected payoffs based on the estimated joint distribution of $(\tilde{c}_i, s_i)$. In particular, we compute the followings: $u_{JV}(M, N, p)$ and $u_S(M, N, p)$. Because p is a continuous variable, we cannot expect many auctions have the same expected cost. This requires us to approximate the set of auctions having the same expected cost in some way. Here, we split the space of p into 2 sub-groups and compute two sets of ex-ante expected payoffs. In other words, we consider the auctions within the same group as homogeneous ones and make use of the variations within the group to infer the ex-ante expected payoffs[15].

We use the following notations to describe the specific process of the inference. $\bar{p}$ and $\underline{p}$ denote the maximum and the minimum of the engineer's estimate in our data. p_{cut} is the cutoff to divide the total number of auctions into equal-sized two sets. We compute two representative engineer's estimates for each group, $\tilde{p_1}, \tilde{p_2}$, they are the mean of the observed expected costs in each group. Let the upper bounds of M, N be $\bar{M}, \bar{N}$. Hence, for each type of entry, S and JV, we infer $2 \times \bar{M} \times \bar{N}$ expected payoffs.

[15] Another possible way is to conduct local estimation using some type of kernel function over the expected cost.

We compute the ex-ante expected payoffs by simulation. When we focus on the single bidder and on one entry pattern (M, N) and one size of auction $k \in \{1, 2\}$, our inference procedure is as follows:

1. Draw 2000 observed single bidders from the auctions in k. Note that, from the estimation of the bidding stage, we know the individual costs of them as well as the scores.

2. For each single bidder i, compute the maximized expected payoff under the entry pattern (M, N) given his pair of $(\tilde{c}_i, s_i)$ and the representative engineer's estimate $\tilde{p}_k$.

3. Take the average of the maximized expected payoffs among the drawn single bidders. This corresponds to $u_S(M, N, \tilde{p}_k)$.

The similar process is applied to all the pair of possible entry patterns, to all the size, and to the entrant as a joint venture.

4.2 Estimation of entry and joint venture formation stage

Remember that we have two entry costs and one matrix as our parameters: (c_{JV}, c_S, R). We take an estimation strategy using MPEC (Su and Judd (2012)) where the equilibrium constraint is (4) and the objective function is

$$LL(c_{JV}, c_S, R) = \sum_{(M,N)} T(M, N) \times \ln g(M, N; c_{JV}, c_S, R).$$

Here $g(M, N; c_{JV}, c_S, R)$ is the equilibrium distribution over the entry patterns and we clarify its dependence on the parameters.

Without any further specification, R is high dimensional object. To stabilize our estimation and to identify the parameters, we assume a specific type of R as described in Section 3.2.1. Here, we further parametrize R by two objects: (Φ, z) where $\Phi : \mathbb{N} \to \mathbb{N}$ maps the number of firms choosing JV as his intention to the number of successfully formed joint ventures and $z \in [0, 1]$, the probability of entry as a single bidder when the firm fails to form a joint venture. As we explained in Section 3.2.1, the number of feasible Φ is finite. This allows us to solve MPEC for each fixed Φ to estimate the other parameters. After estimations under all the possible Φ's, we choose the pair that maximize (minimize) the value of the objective functions.

Furthermore, to reduce the number of possible Φ's, we use the following function to express Φ[16]:

$$\Phi(L_1; \alpha) = \max\left(0, \lfloor \alpha \times \ln \frac{L_1}{2} \rfloor\right).$$

Here α determines the shape of Φ. So in the estimation, we first identify the set of α's which gives the feasible Φ's and then solve MPEC for each possible α's to determine the best set of estimates.

This estimation procedure is one way to estimate the static entry game under incomplete information, such as Seim (2006), via MPEC. The standard entry game corresponds to the case where the outcome mixing matrix R is the identity matrix and the number of intention patterns and the number of the entry patterns are the same. In our case, because we do not know the detail mechanism to govern the joint venture formation, we have to include non identity and unknown R in our estimation.

We implement this constrained maximization problem in JuMP using Ipopt as a solver. When we set the number of potential entrants to 11 and focus on the Φ which finally reaches 4 at $L_1 = 11$, the number of feasible Φ is 7. So we solve 7 MPEC problems to get the estimation result.

4.3 Identification and Monte Carlo simulation

We argue informally the identification of the parameters in the entry and joint venture formation stage: Φ, p and c_{JV}, c_S. Our objective here is to state that the true prediction vector P, which is computed as the equilibrium under the true set of parameters, cannot be generated under any other set of parameters.

The prediction vector P is a mixture of the columns of the outcome mixing matrix R where the weights are the distribution over the intention patterns Q. Because we assume the

[16]This restriction is due to the computational resource constraint.

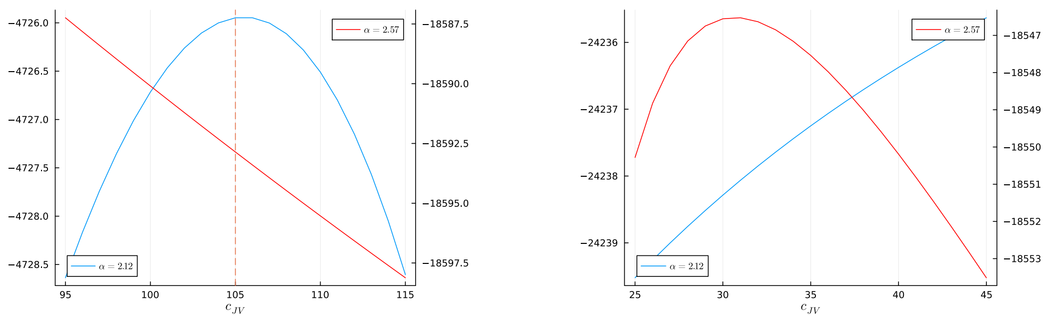
potential entrants choose their intentions independently, this Q represents a probabilities generated by a multinomial distribution. In other words, the weights in the mixture are constrained by the model. Under this restriction, two different outcome mixing matrices cannot generate the same prediction vector even by arbitrarily choosing other parameters.

This is easily seen when we focus on two extreme entry patterns: no additional single bidders entering after failing to form a joint venture and all the potential entrants who fail to form a joint venture enter as single bidders. Pick one number of joint ventures and put a focus on the entry patterns corresponding to it. Note that each column of R is just a binomial distribution. The prediction probability of the first entry pattern is $\sum_i (1-p)^{n_i} \times w_i$ where i denotes the relevant column index and n_i is the number of potential entrants who fails to form a joint venture and w_i is the weight on the column i. The same probability for the second case is $\sum_j p^{n_j} w_j$. Because both of them are monotone in p, we can find appropriate p's for the two extreme cases for any weight and for any set of relevant columns. But the weights are not arbitrary, we cannot always find just one p consistent with the two cases.

In practice, to cover the support of the function Φ, we need the auctions which have many potential entrants try to form a joint venture and the auctions which reduces the incentive to form a joint venture to identify Φ. To do so, we do not separate R for each class of auctions, instead we have just one R governing the number of joint venture in all auctions.

We conduct a Monte Carlo simulation to show our estimation strategy and validate the implementation result. We set the number of potential entrants to 5 and set the maximum number of joint ventures to 2. Under this setting, we solve the equilibrium of our model under a set of ex-ante expected payoffs, which is computed from our data. Based on this equilibrium distribution, we draw a set of realized entries, which is the simulated data in our experiment.

Our parameter setting is as follows: $c_{JV} = 105, c_S = 55$ and $\alpha = 2.12$. In the current setting, we have another possible α which gives a feasible Φ which is $\alpha = 2.57$. In this experiment, we fixed c_S to the true value and compute the value of the log-likelihood for the several values of c_{JV} and the two α's. Figure 4 summarizes the two log-likelihood functions, where the left axis represents the value of the log-likelihood for the true α and the right axis represents the same one for the higher α. Panel (a) of Figure 4 shows the log-likelihood



(a) Maximizer for the true α

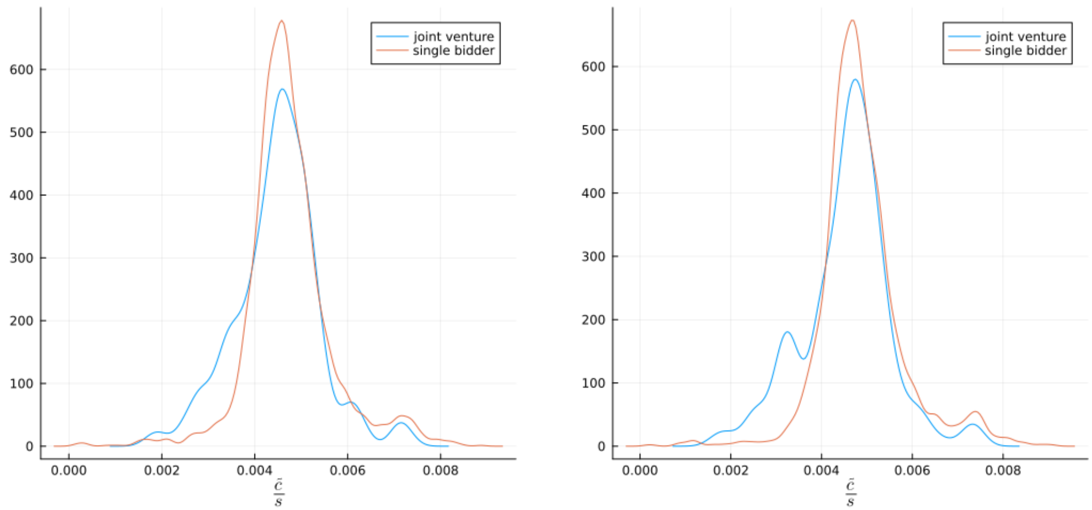
(b) Maximizer for the wrong α

Figure 4. The log likelihood function of the two different α's. The blue line is obtained when we use the true α and the red line is the obtained when we use one wrong α. Panel (a) is the snapshot around true entry cost. Panel (b) is the snapshot around the maximizer of the log likelihood of the wrong α.

functions around the true value of c_{JV} which is 105. We find that, when we adopt the true α, which is 2.12, the log-likelihood takes its maximum around the true value. On the other hand, Panel (b) of Figure 4 shows the region around the maximizer of the log-likelihood function for the wrong α, which is $\alpha = 2.57$. As you find, the maximized lo-likelihood for the true α is around -4726 while the same one for the wrong α is around -18547. THhis difference allows us to identify the true shape of Φ.

5 Estimation Results

This section presents a series of estimation results for the structural model discussed in the previous sections. Section 5.1 shows the estimation results for the bidding stage: The retrieved individual costs and the ex-ante expected payoffs. Section 5.2 shows the estimation results for the entry and joint venture formation stage. In particular, our main interest here lies in estimating (i) the outcome mixing matrix, in particular, Φ, which determines the number of successfully formed joint ventures and (ii) the additional entry cost as a joint venture.



(a) A Homoskedasticity Case (b) A Heteroskedastic Case

Figure 5. Density estimations of $\frac{\tilde{c}_i}{s_i}$. Panel (a) demonstrates the result when we assume homoskedastic variances. Panel (b) is the result when we use type-dependent variance estimations. In each panel, the blue line represents the density for joint venture and red line represents the density for single bidder.

5.1 Bidding stage

First, we show the estimation results for the bidding stage, assuming, the degree of polynomial to 1 when estimating the distributions of the logarithm of effective bids.[17] Figure 5 depicts the estimated densities of $\frac{\tilde{c}_i}{s_i}$ for single bidders and joint ventures, assuming homoskedastic variance in Panel (a) and heteroskedastic variance in Panel (b). This is because the variances of the effective bids of single bidders and joint ventures could be different. We retrieve $\tilde{c}_i$ and take the fraction $\frac{\tilde{c}_i}{s_i}$ for every i in the data and then plot the estimated densities based on these empirical data points. In each panel, the blue line demonstrates the density for joint ventures, whereas the red line demonstrates the density for single bidders.

There are two important observations in this figure: (i) the estimated distribution for joint ventures has first order stochastic dominance over the estimated distribution for single bidders in both panels and (ii) the density of the cost-score ratio of joint ventures has two-modals. As the fraction $\frac{\tilde{c}_i}{s_i}$ is smaller when the entrant i is more competitive in the current scoring auction, this result indicates that joint ventures are more likely to win the auctions.

[17] We check the robustness of our results by changing the choice of this degree of polynomial. Figure A3 in Appendix demonstrates the results when we set the degree of polynomial is equal to 2.

And, as we see in Panel (f) of Figure 1f where we find that the distributions of score for single bidders and joint ventures are almost identical, joint ventures are more competitive due to cost reduction which, we believe, is from cost synergies.

Also, the cost distribution being bi-model suggests that there are two types of joint ventures: joint ventures who materialize the cost synergies and who does not materialize the cost synergies. As the latter type of the joint venture has similar cost distribution as single bidders, the social benefit of joint ventures comes from the former type of the joint venture. "What makes the joint venture more cost effective? And how can we facilitate the cost efficiency?" is a very important topic for future studies and is beyond the scope of our studies because this paper does not put any structure on how the cost synergies materialize.

Based on the estimated distribution of $(\tilde{c}_i, s_i)$, we then estimate the ex-ante expected payoffs in each auction. Figure A4 shows the estimated ex-ante expected payoffs for a single bidder and a joint venture, dividing the auctions into two classes by its engineers estimates; If an engineers' estimates of an auction i is below median, it is categorized into small-sized auction, otherwise large-sized auction, as discussed in Section 4.1.1. For each pair of the number of a joint venture, M, and the number of single bidders, N, we plot the estimated ex-ante expected payoff. In general, we find that the payoffs are larger when the number of entrants is smaller, which is consistent with the theoretical prediction[18].

To check the fit of our model, we compare the observed bids with the optimal bids obtained as the solutions to the expected profit maximization problem, defined in Equation (1). Figure A5 compares the observed effective bids with the simulated optimal effective bids for each category. The orange line depicts the estimated density of the observed effective bids, whereas the blue line depicts the estimated density of the simulated bids. The comparison confirms that the model fits the data reasonably well; the simulated bid distribution and the observed bid distribution have their peak at similar points. However, there are discrepancy as well; the simulated distributions have thinner tails than the observed bids. As we fit the model with a limited number of parameters and smooth distributional assumptions, we cannot avoid the simulated distribution to have thicker tails. We would be able to fit the

[18] The value for the case when there is a single entrant is set to the corresponding expected cost in Figure A4.

model better if we would increase the number of parameters. Doing so comes with a cost that the computation may become infeasible and the reliability of the estimates may become vulnerable to outlier observations. Given this trade-off, we decide to adopt the current specification, splitting the auctions to two class.

5.2 Entry and joint venture formation stage

In this section, we show the estimation results for the first stage. Figure 6 depicts the estimated Φ with the orange line and the upper bound of the number of joint ventures with the blue line. The x-axis shows the number of potential bidders with the intent to form a joint venture, L_1, and the y-axis shows the number of realized joint ventures, M. The estimated Φ indicates that no joint ventures are formed until 3 potential entrants try to form a joint venture. If four firms attempt to form a joint venture, then one joint venture will be formed. The number of joint ventures formed increases, as the number of firms attempt to form a joint venture.

The difference between the two lines represents the friction in joint venture formation. Forming a joint venture requires the potential entrants to find another partner, and no joint venture is formed even if there are two potential bidders with the intent to form a joint venture. The non-linearity in Φ suggests that the friction is the smallest when the number of potential bidder with the intent is medium. It could be that (1) finding a partner is difficult when the potential bidder with the intent is small and (2) a congestion effect exists when the number of potential bidder gets large.

Table 3 shows the estimation results of the cost parameters for each α. The α with the highest log-likelihood, $-1,955$, and the estimated costs for joint ventures and single bidders are $\alpha = 2.413$, $c_{JV} = 19.368$, and $c_S = 11.002$, respectively. The standard errors indicate that the difference between c_{JV} and c_S is statistically significant. Entry as a joint venture requires the firms to spend additional 8.366 million yen. This highlights the existence of the adjustment costs to manage the joint venture, which is well recognized in the merger literature. This additional entry costs are equivalent to 0.21% of the average engineers' estimates (expected costs) in the larger-sized auctions and 0.85% in the smaller-sized auctions. While these numbers are very small, when we compare this additional costs

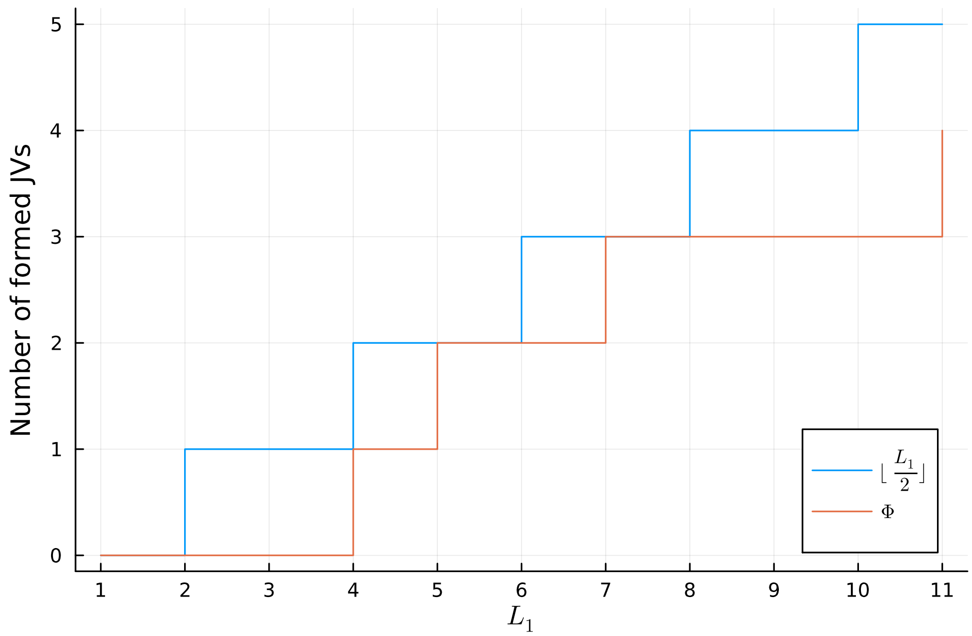


Figure 6. Estimated pattern of the formation of joint ventures. The horizontal axis is the total number of potential entrants who choose JV. The vertical line is the number of formed joint ventures. Blue line is the upper bound for the number of joint ventures, i.e., $\lfloor \frac{L_1}{2} \rfloor$.

Table 3. Estimation Results in Entry Stage

α	LL	c_{JV}	c_S
2.373	-1963	18.651	11.013
2.413	-1955	19.368	11.002
		(0.511)	(0.032)
2.453	-2065	14.266	10.662
2.563	-2062	14.104	10.665
2.683	-2054	14.053	10.667
2.794	-2039	16.408	10.608
2.904	-2722	2.570	0.474

Notes: The unit of the cost is $1,000,000$ yen. Standard errors are computed only for α that gives the highest log-likelihood, which are contained in the brackets below the estimated values.

to the inferred ex-ante expected payoffs, it becomes a significant factor in the entry decision, especially when the probability of winning the auction is taken into account. For example, in the smaller-sized auctions, when there are one joint venture and one single bidder in the auction, the additional entry costs account 23.72% of the expected payoff for joint venture. We conclude that this additional entry cost can be a driving force of the small number of observed joint ventures in spite of their competitiveness in the auction stage.

6 Counterfactual Simulations

Given the estimated model, we conduct a counterfactual analysis where we change the entry costs of joint ventures to investigate whether the government should further pursuit joint venture formations in procurement auctions.[19] On the one hand, joint venture formation should be encouraged from the viewpoint of cost synergies, according to our estimation results. On the other hand, as we mentioned in the introduction, increasing number of joint ventures may decreases the incentive to participate in the auction due to the competitiveness of the joint ventures. We therefore must quantify the gross benefits of this policy, taking into account these two countervailing effects.

Measure of Outcome Efficiency To measure the efficiency of auction outcomes, we define *procurement efficiency* for a set of auctions as follows:

$$\frac{\text{total amount of engineer's estimate} - \text{total amount of winning bid}}{\text{total amount of engineer's estimate}} \times 100.$$

$$\frac{\sum_j (\text{Engineer's Estimates})_j - \sum_j (\text{Winning bid})_j}{\sum_j (\text{Engineer's Estimates})_j} \times 100.$$

In the small-sized auctions, the observed level of procurement efficiency is 11.31 and the same one for the large-sized auctions is 12.25. In the following counterfactual analysis, we compute this value for each class of auctions when the government changes the additional entry cost to enumerate the gross effect on the efficiency of the procurement auctions.

For this counterfactual analysis, we need simulated sets of auctions and the entrants. Below we describe how to generate them based on our estimation results. First, set the total

[19] In principle, there are two possible policy interventions to encouraging joint venture formation: (i) lowering entry costs as a joint venture, and (ii) changing scoring rules to give preferential treatment for joint ventures. Our data do not contain the detailed information on the score for each bidder, which prevents us from conducting the second type of counterfactual simulations. Therefore, in this counterfactual simulations, we focus on the former type.

number of auctions, T, for a fixed class of auction, p,

1. From the empirical distribution of the expected costs, we draw T expected costs.
2. Based on the estimated values of (α, c_S, z) and an arbitrarily set c_{JV}, compute the equilibrium prediction p^{fp} and the distribution over the entry patterns.
3. Draw the entry pattern for each auction based on the above equilibrium distribution.
4. Draw the individual cost factor and the score for each firm from the estimated distribution of individual cost and score for single bidders and joint ventures.
5. Compute the optimal bid by solving the optimization problem for each bidder.
6. Determine the winner in each auction and decide the winning bid by comparing the effective bids.

We have two technical remarks on this counterfactual simulation. First, we set the range of c_{JV} as $c_{JV} \in [7, 30]$ to compute the procurement efficiencies. In the range, we check the model can be solved, i.e., we obtain the equilibrium level of predictions and the corresponding distribution over the entry patterns. Out of this range, our fixed point problem might not behave well, which makes it hard to compute the counterfactual distribution. Having said that, we still believe that $[7, 30]$ is enough to consider the realistic situations. Second, as we do not specify or estimate the distribution of the expected costs for each class, we use the same distribution for both classes.

6.1 Simulation Results

Figure 7 demonstrates procurement efficiencies for each class of auctions, when we change the cost of entry as a joint venture. The blue solid line represents the computed procurement efficiency for the small-sized auctions, whereas the orange solid line represents the same one for the large-sized auctions. The green dotted vertical line corresponds to the estimated value of the entry costs as joint venture, $\tilde{c}_{JV}$, and the purple dotted vertical line represents the estimated value of the entry costs as single bidders, $\tilde{c}_S$

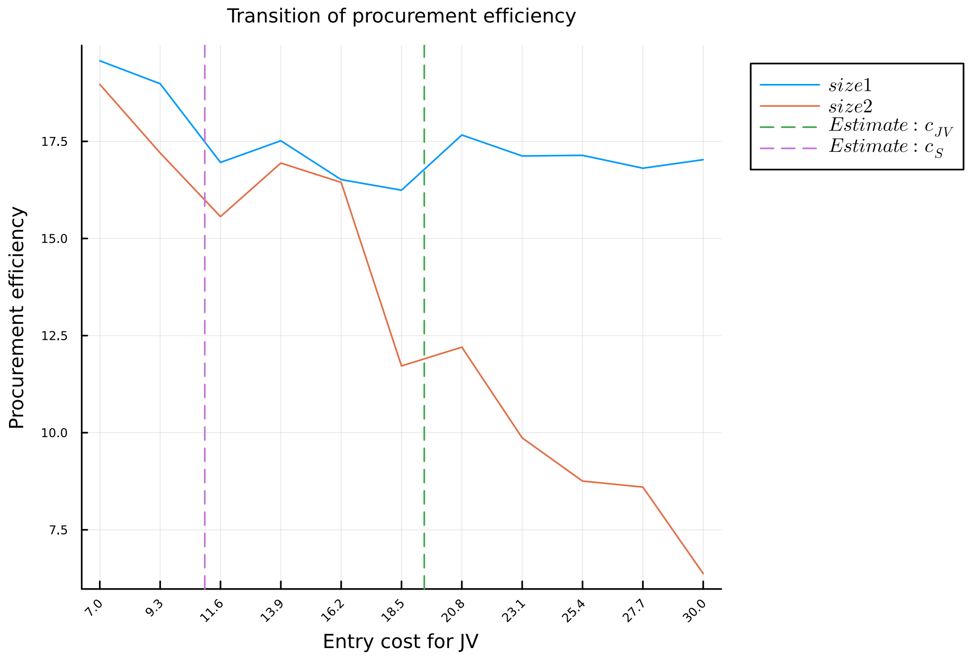


Figure 7. Counterfactual procurement efficiency vs the entry cost as a joint venture

Notes: The blue solid line represents the computed procurement efficiency in the smaller-sized auctions, whereas the orange solid line represents the same one for the larger-sized auctions. The green dotted line corresponds to the estimated value of the entry costs as joint venture, $\tilde{c}_{JV}$*, and the purple dotted line represents the estimated value of the entry costs as single bidders,* $\tilde{c}_S$*.*

From the figure, we can immediately see that the impacts of changing entry costs for joint ventures has heterogeneous effects with respect to the size of auctions. When we focus on small-sized auctions, changing entry costs for joint ventures would not change procurement efficiency. This is due to the increasing number of entrants by decreasing the joint venture: i.e., the firms who would enter as a joint venture entry as single bidders separately. This leads to more competitive bids. On the other hand, for the larger auction class, we find a decrease in procurement efficiency. This is because we cannot expect the cost reduction associated with the synergy of the joint venture. For larger-sized auctions, the effect of decreasing the cost efficiency overwhelms the effect of increasing the number of entrants.

Next, we analyze the effect of encouraging joint venture formation by decreasing the additional entry cost. In the area between two dotted vertical lines in Figure 7 corresponds to this type of policy. Although the gross effects are again heterogeneous in the size of auctions, in particular in the larger-sized auctions, we find the mild reduction in the additional cost is the key to increase the procurement efficiency. Too much reduction induces more entry of joint ventures, which threatens the other potential entrants. Then the pro-competitive effect of cost synergy is overwhelmed by the anti-competitive effect of the decreasing number of bidders. On the other hand, by decreasing the additional cost a little bit, the auctioneer can benefit from the cost synergy of joint ventures. This is shown in the sharp decrease in just left of the green dotted line.

Overall, changing the additional costs as a joint venture influences the larger-sized auctions more than the smaller-sized auctions. The blue line is almost constant, regardless of c_{JV}. This heterogeneity also helps the policy maker to focus on the most sensitive type of auctions. Moreover, the policymakers should note that this type of cost changing policy is delicate. In the larger-sized auctions, the procurement efficiency changes a lot by a small change in c_{JV}. This is due to the low expected payoffs in the auction stage. Hence, the level of encouragement should be determined gradually as the government observes the realized impact.

7 Conclusion

We study the joint bidding in procurement auction using the Japanese procurement data, developing a two-stage model where the bidders make their decisions on entry and joint venture formation in the first stage and they subsequently bid in the second stage. The results from the second stage highlight the presence of cost synergies that benefit the joint ventures. This is evident by comparing the estimated joint distribution of individual project cost and the score for the single bidders with the same one for the joint ventures. Furthermore, though joint ventures bid stronger than single bidders do on average, joint ventures occasionally bid weaker than single bidders do, suggesting that the cost synergies involves uncertainty at the time of joint venture formation, which is unknown even for the forming parties.

Our empirical results in the first stage indicate the existence of search frictions and adjustment costs associated with joint venture formation, which act as obstacles to form a joint venture. The presence of joint ventures may discourage the entry incentives of single-bidders, as joint ventures become relatively stronger when formed successfully. Thus, from the viewpoint of procurers, when optimizing government procurement efficiency, it is crucial to consider both a pro-competitive effect driven by cost synergies and an anti-competitive effect resulting from the lower number of bidders. Our counterfactual simulations show that, depending on the size of auctions, the excessive promotion of joint venture formation through lowering entry costs as joint venture could be worsen procurement efficiency, due to a reduction in the number of participating firms.

Lastly, we describe the limitations of our study and the possible future research directions. Our model assumes homogeneity among potential entrants and focuses solely on the realized number of joint ventures and single bidders, without considering their individual identities. This simplification is motivated by the empirical context of our study, where all potential bidders qualified for the World Trade Organization (WTO) type auction must be pre-registered as qualified companies. Consequently, we contend that heterogeneity among companies is not a deterministic factor in assessing the effectiveness of joint ventures. Nevertheless, incorporating identity information into the analysis could enable a more detailed examination of the mechanisms underlying cost synergies, search frictions, and adjustment costs. In essence, policymakers would benefit from understanding which specific pairs of companies are more effective in achieving desired outcomes.

Our estimation method accommodates such heterogeneity by expanding the range of possible entry patterns and intention patterns. Although in this paper, we define the entry pattern as the combination of the number of joint ventures and the number of single bidders, it is possible to consider the power set of entry decisions made by each potential entrant, thereby accounting for their identities. However, it is important to note that such an approach substantially increases the size of the outcome mixing matrix, which can impede efficient and stable estimation. Consequently, employing this method would necessitate a relatively small number of potential entrants to maintain computational feasibility and reliability in the estimation process.

Another important consideration is the dynamic aspects of joint venture formation. For example, the costs associated with the joint venture formation may decrease as firms accumulate the experience by forming joint ventures or even just attempting to form joint ventures. Taking into account such a learning-by-doing effect may be an interesting research direction.

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Appendix A Additional figures

Appendix A.1 Collusive behavior

We demonstrate the results for collusion screening tests by Kawai and Nakabayashi (2022*b*) for each subset of region in Figure A1 and for each year in Figure A2.

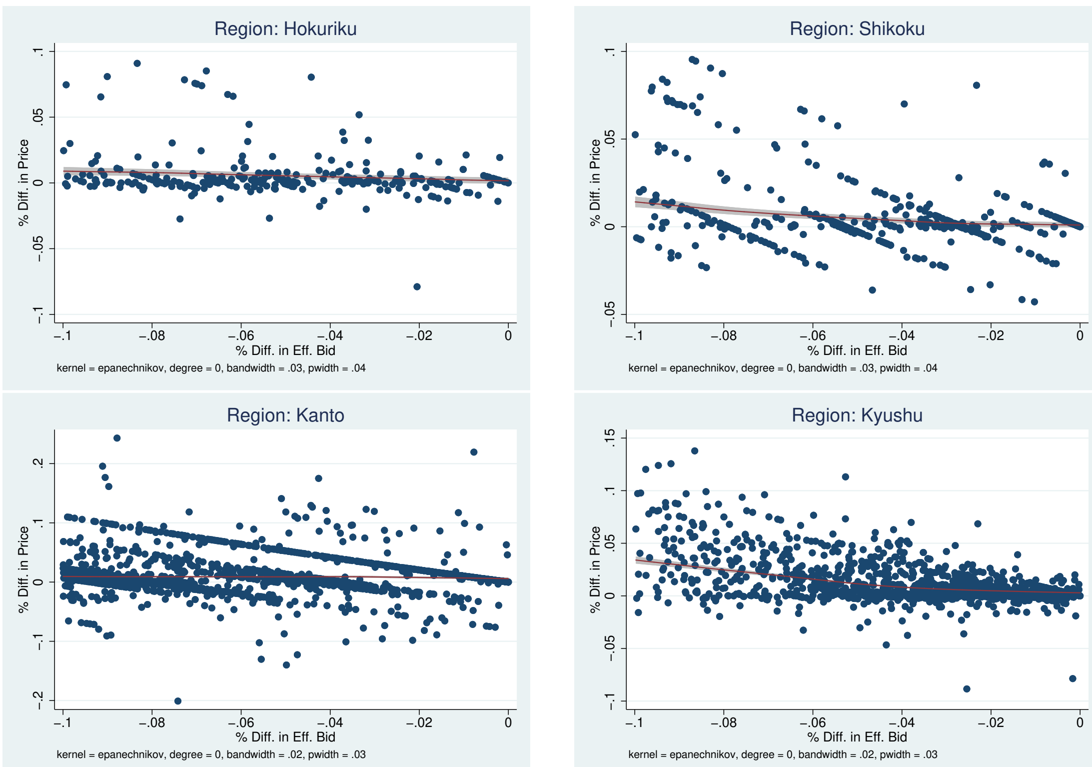


Figure A1. Region-by-Region Collusion Screening Tests by Kawai and Nakabayashi (2022*a*)

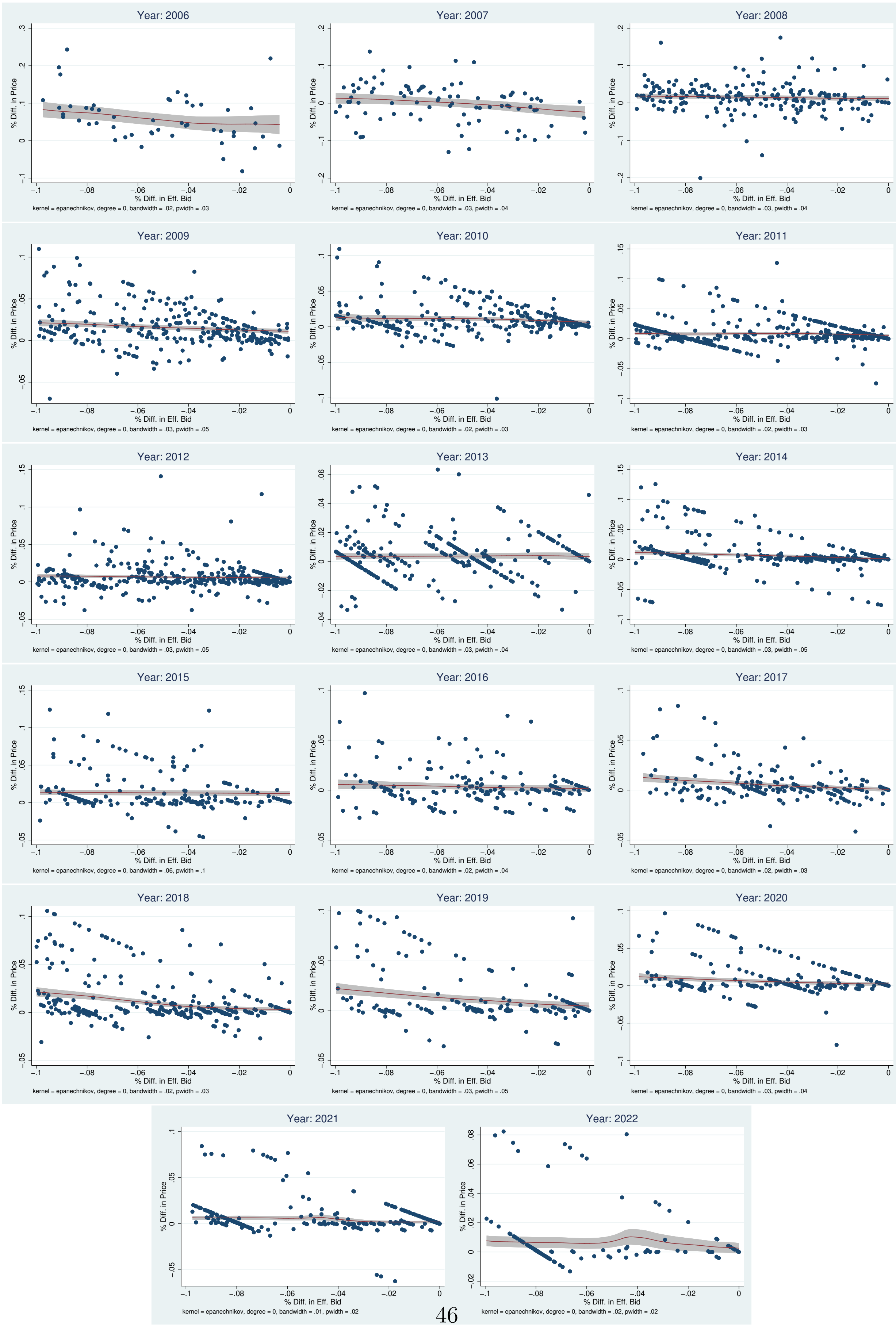
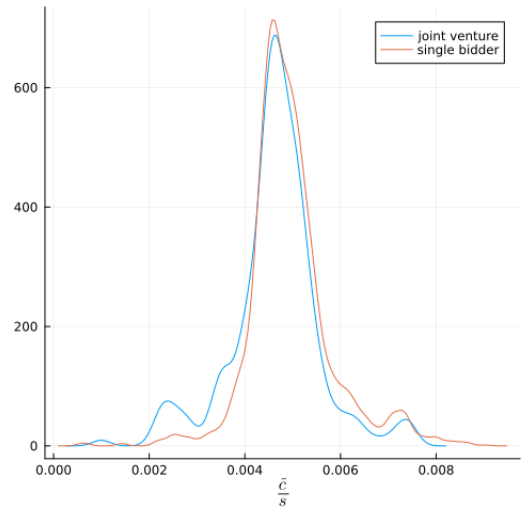


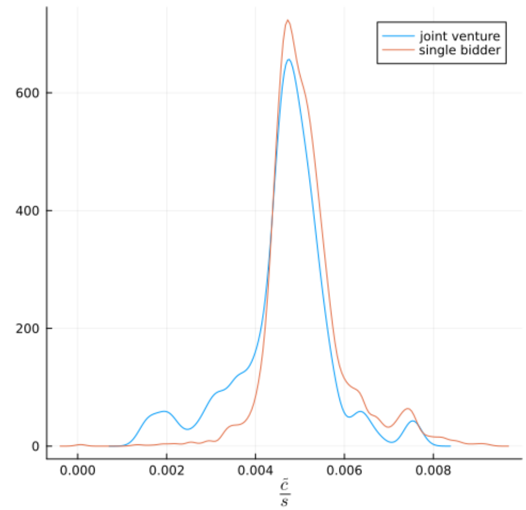
Figure A2. Year-by-Year Collusion Screening Tests by Kawai and Nakabayashi (2022*a*)

Appendix A.2 Estimates of the density of $\frac{\tilde{c}_i}{s_i}$

Figure A3 shows the estimation results when we use the polynomials with degree 2. Basically, we see the same pattern as in the case of degree 1.



(a) Homoskedasticity case

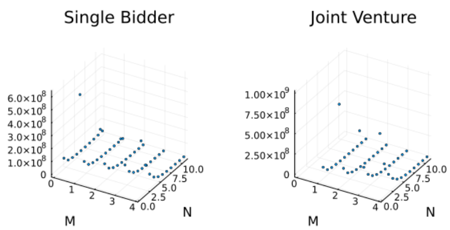


(b) Type dependent variance case

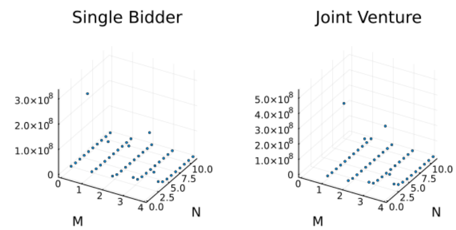
Figure A3. Density estimations of $\frac{\tilde{c}_i}{s_i}$. We focus on the entrants in the auctions in which at least one joint venture participate. Blue line represents the density for joint venture and red line represents the density for single bidder. Panel (a) is the result when we assume homoskedastic variances. Panel (b) is the result when we use type-dependent variance estimations.

Appendix A.3 Ex-ante expected payoff

Figure A4 shows the ex-ante expected payoffs for each class of auctions. The results here are obtained when assuming the polynomial of degree 1.



(a) Smaller size

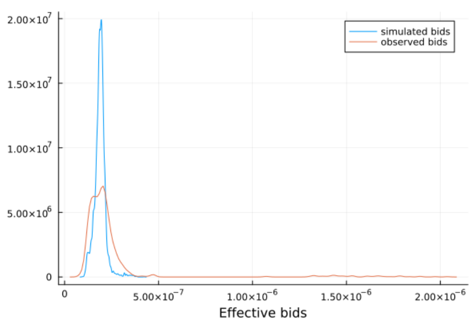


(b) Larger size

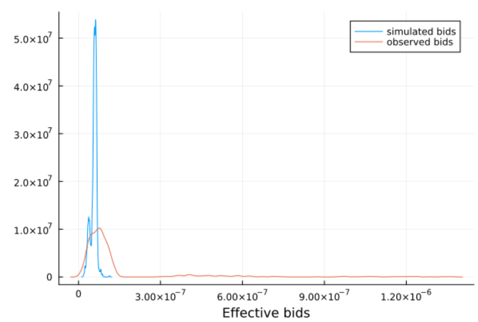
Figure A4. Estimates of the ex-ante expected payoffs. For each category of auctions, we compute the expected payoffs by entering the auction for a single bidder and a joint venture given the number of entering single bidders and joint ventures.

Appendix A.4 Model fit

Here we compare the simulated optimal effective bids with the observed effective bids. Figure A5 shows the comparison results for all the classes of auctions.



(a) Smaller size



(b) Larger size

Figure A5. Comparison of the observed bids with the computed optimal bids. For each category of auctions, the blue line represents the estimated density function of computed optimal effective bids solving the profit maximization problem and the orange line is the estimated density of the observed effective bids.