Joint Bidding, Information Sharing, and the Winner's Curse in First-Price Common Value Auctions

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Abstract

In a first-price common value auction, bidders tend to bid less aggressively in consideration of the winner's curse, especially when competition, limited information, or high risks are involved. Joint bidding alleviates these problems and potentially benefits a seller by relieving the winner's curse and encouraging more aggressive bidding. The analysis on joint bidding is important for a government to ban or allow joint bidding in procurement auctions with common value features. However, there is little empirical evidence of that. In this paper, we study joint bidding behavior and its impacts on bids and the winner's curse using the Outer Continental Shelf (OCS) auctions from 1954 to 1975. We provide reduced-form evidence of the effect of joint bidding on bidding strategy and bid levels by introducing a novel instrument leveraging a new dataset of firms' office addresses recorded in lease contract agreements. We find that joint bidding leads to 75% higher bids on average, implying a potential policy implication for allowing joint bidding in the OCS auctions.

Keywords: Joint bidding, winner's curse, first-price auction, common value auction.

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1 Introduction

In common value auctions, bidders are concerned about overestimating the unknown true value of an auctioned object relative to others' valuations ("the winner's curse"), which results in lower bid amounts than they would submit without such concern. This naturally raises the question of whether bidders can employ any other strategy to mitigate the winner's curse and thus increase their bid amounts. We posit that joint bidding, a practice of submitting a single bid by a consortium of multiple firms, can serve as one such strategy. We further claim that joint bidding could benefit even the seller, as colluding buyers tend to submit higher bids. Understanding the advantages of joint bidding holds significant economic implications, particularly in procurement auctions involving common value objects such as gas and oil rights. This understanding can offer insights into whether governments should permit or prohibit joint bidding. A change in the auction scheme can directly translate into increased auction revenues and public funds.[1] Given these considerations, an intriguing question arises: Does collusion among bidders stifle competition and lead to lower bid amounts, or could it operate through different mechanisms?

This paper provides empirical analyses for first-price sealed-bid auctions with common values and bidder asymmetry from joint bidding, using the data of oil and gas exploration rights in U.S. Outer Continental Shelf. We conduct the reduced-form analysis that illustrates how joint bidding affects the bidding strategy (or bid levels) compared to solo bidders in the auction game. To solve the potential endogeneity problem in joint bidding behaviors, we propose a novel instrument by exploiting a new dataset of firms' office addresses recorded in lease contract agreements.

Strategic collusion among bidders may drive up the bid levels through four different channels. First, joint bidding reduces the number of competitors, which has an ambiguous impact on a firm's bid. On the one hand, a firm's willingness to pay would be lower in a less competitive environment. On the other hand, buyers may expect the winner's curse to be less severe under the lower level of competition and therefore tender a higher price. Second, information sharing within a consortium would raise the quality of the signal about the true value, leading to less fear of the winner's curse and a higher bid. Third, joint ventures can relax their budget constraints and bid higher. Finally, a consortium can share risks regarding the real-

[1] For instance, the U.S. federal government raised $4.1 billion of revenues from Outer Continental Shelf (OCS) oil and gas activities in the fiscal year of 2021 and allocated the highest portion to the General Fund of the U.S. Treasury. See https://www.boem.gov/regions/gulf-mexico-ocs-region/oil-and-gas-gulf-mexico.

izations of the future states and thus is likely to bid higher. To sum up, joint ventures may submit higher bids unless the negative effect of lessened competition outweighs the other positive effects of strategic alliance. Accordingly, an empirical analysis using appropriate data is necessary to determine the impact of a joint venture on bid amounts.

We examine the effect of joint bidding in oil and gas exploration rights auctions in the U.S. Outer Continental Shelf (OCS). The OCS auctions are an ideal setting for testing the effect of joint bidding due to the common value nature of the auction and the prevalence of joint bidding among participants. However, the federal government banned joint bidding among eight large firms in December 1975. Hence, we restrict our analysis to the period when joint bidding was freely allowed.

We propose a novel instrument to address the endogeneity problem associated with a firm's joint bidding decision in our analysis. The main challenge in conducting a reduced-form analysis in our context is that our key regressor, the decision to engage in joint bidding, is endogenously affected by unobserved tract and firm heterogeneities. We address the former source of endogeneity by controlling for the number of joint and solo bidders (Campo et al., 2003) and ex post net revenue of a given tract (Hendricks et al., 2003). To address the latter, we build a new instrument based on the proximity of office addresses among actual bidders. As firms in close proximity are more likely to form a consortium due to lower transaction costs,[2] the instrument would satisfy the relevance restriction. The exclusion restriction is also satisfied since the closeness of firms' office addresses may affect bid amounts only through their joint bidding decision. The instrument is time-varying as the list of actual bidders varies across auctions. To construct the instrument, we collected raw data for office addresses from the government registry and winners' lease contracts up to the five-digit zip code level. To supplement our analysis, we suggest another instrument, the historical occurrence of joint ventures amongst the actual bidders. This instrument is based on the idea that firms tend to maintain partnerships to some extent, thus avoiding search costs associated with finding new partners.

We also utilize the number of potential bidders (Hendricks et al., 2003) to address the endogeneity of the overall competition level. Examining the effect of forming a joint venture poses challenges due to the bidirectional relationship between collusion formation and the competition level. Forming joint ventures affects an auction's competition level and bidder structure (Hendricks and Porter, 1992). Conversely, high

[2]Given our study period ranges from 1954 to 1974, communication costs could have mattered much more than nowadays when seeking a partner.

competition may incentivize firms to collude to reduce competition and improve their winning chances. Thus, competition is endogenously determined. To better understand how joint bidding and the resulting number of joint bidders affect bids, we investigate how a change in the composition of bidder types, characterized by the number of joint and solo bidders, influences the average bidding behavior of auction participants given an overall competition level. To endogenize the overall competition level, we identify potential bidders who participated in auctions for neighboring tracts prior to the sale date of a given tract, and we use the number of potential bidders as an instrument.

In the reduced-form analysis, we find that firms tend to bid higher when they engage in joint bidding. Our 2SLS estimation reveals that joint bids are 75% higher than solo bids, while OLS shows a 36% difference. The comparison between 2SLS and OLS results suggests that our instruments correct the downward bias introduced by unobserved bidder heterogeneity. Additionally, we categorize joint ventures into mutually exclusive and exhaustive categories. Our analysis reveals that consortia involving large firms are inclined to offer higher bids than large solo firms. We further study the effect of bidder structure and competition on average bids. The 2SLS results indicate that one more joint bidder (and hence one less solo bidder) leads to an increase in the average bid by approximately 30% given an overall competition level. These findings support the claim that collusion may elevate bid amounts and carry a potential policy implication for allowing joint bidding in the OCS auctions.

This paper contributes to three strands of literature: bidder asymmetry, bidding rings, and the winner's curse. We estimate how joint bidders bid differently compared to solo bidders and how changes in bidder structure resulting from joint bidding impact average bids using our novel instrument, contributing to the literature studying bidder asymmetry (Hendricks and Porter, 1988, 1992; Hendricks et al., 1994; Campo et al., 2003; Somaini, 2020) and a bidding ring (McAfee and McMillan, 1992; Hendricks et al., 2008). Additionally, we find that consortia involving large firms submit higher bids than large solo firms, which conveys a potential implication that large-involved consortia may suffer less from the winner's curse than large solo bidders. This finding adds to the literature on measuring the winner's curse (Hong and Shum (2002); Hendricks et al. (2003); Somaini (2020)), although a structural approach is necessary to explicitly measure the winner's curse of joint and solo bidders and will be provided in the next version of this paper.

The remainder of the paper proceeds as follows. Section 2 describes the auction mechanism and data. Section 3 provides the reduced-form design and construction of the instruments. Section 4 reports the reduced-form evidence based on OLS and 2SLS estimation methods. Section 5 briefly concludes the paper.

2 Data Description

2.1 Auction Mechanism

We first describe the functioning of the OCS oil and gas lease auctions along with the expected effect of joint bidding on its bid amount. During the study period of 1954-1974, the U.S. federal government organized the sale of multiple tracts on specific dates, typically occurring once or twice a year in our sample.[3] On average, a sale included 81 tracts in our sample, and tracts were often distributed across different areas. The list of the tracts available for auction was announced to the public before the actual sale dates. All tracts in a sale were auctioned simultaneously on the day of the sale.

If firms opted to form a joint venture, they would enter into an "area of mutual agreement". The agreement specifies a set of tracts within a designated area where participating parties consented to evaluate their values collectively, share the exploration costs, and coordinate their bidding efforts (Hendricks et al., 2003). The agreement was known to other oil companies (Hendricks et al., 2003). Both joint ventures and individual firms would acquire and analyze comprehensive geophysical surveys of specific tracts they were interested in before actual bidding (Hendricks et al., 2003). Subsequently, they would select a subset of tracts and submit sealed bids. However, firms were unaware of which firms were bidding on which tracts until the Department of the Interior opened all envelopes and announced each participant's bid amount.[4]

By forming a consortium, participating firms may increase the bid amount beyond what they would submit individually. There are four channels: First, the reduced number of competitors may mitigate concerns about the winner's curse and result in a higher bid. Second, by jointly collecting and evaluating information about a given tract, a consortium is likely to bid higher with less fear of the winner's curse. Third, a relaxed budget constraint via joint bidding may also contribute to a larger bid. Fourth, consortium participants can hedge risks associated with the realization

[3]There were a few exceptions to this pattern: no sales between 1956 to 1958, three sales in 1962 and four sales in 1974.

[4]For further information on how the OCS auctions work and oil firms behave, refer to Hendricks et al. (2003).

of future states and thus submit higher bids. However, the reduced competition resulting from collusion formation may lead to a decrease in the bid amount due to the elimination of competitors ("the competition effect"). With fewer rivals, firms can secure victories more easily, potentially reducing their incentive to offer higher bids. Therefore, empirically examining whether joint ventures offer higher bids than individual bids becomes crucial to understanding the overall impact of consortium formation.

Prior to 1975, firms were allowed to seek a joint bidding partner without restrictions. However, the Energy Policy and Conservation Act of 1975 introduced a new regulation that prohibited joint bidding among major oil and gas firms whose average global daily production exceeded 1.6 million barrels of crude oil (or equivalents) (Department of the Interior, 2016). Thus, we restrict ourselves to the period between 1954 and 1974 for our main analyses. And the post-enactment period will be reserved for counterfactual analyses to assess the impact of the ban on bidding behavior and the winner's curse.

2.2 Overview of Data

We use the OCS auction dataset, which contains information on the auctions of oil and gas tracts in the Gulf of Mexico region: Texas and Louisiana.[5] The dataset covers 3,007 oil and gas auctions from 1954 to 1979, capturing lease characteristics, bidding details, drilling activities, production data, and cost information. Our main analysis focuses on 2,202 auctions from 1954 to 1974. In particular, the dataset contains ex post realizations of common tract values, defined as discounted revenues less discounted drilling costs and royalty payments. We utilize the ex post value and assume it to be the true common value.

To supplement the dataset, we collect office addresses of auction participants up to the five-digit zip-code level at the time of signing a lease contract after winning an auction, obtained from the Bureau of Safety and Environmental Enforcement (BSEE) Data Center. It allows us to identify the specific office location of an oil firm involved in the auction, even if it differs from the firm's headquarter addresses. In cases where lease contracts are unavailable, or a firm never won an auction, we collect addresses registered in the BSEE's oil company list.

[5]The data used in this research were made available by the Center for the Study of Auctions, Procurements, and Competition Policy at Penn State with support from the Human Capital Foundation (http://www.hcfoundation.ru/en/) and downloaded from the following website: https://capcp.la.psu.edu/data-and-software/outer-continental-shelf-ocs-auction-data/.

2.3 Summary Statistics

Before delving into the reduced-form analysis, we show two tables of descriptive statistics to examine the patterns observed in our sample. Table 1 shows summary statistics for all observations in our sample. Panel A of table 1 presents bid-level statistics for a total of 8,054 bid observations, with approximately 51% of them submitted by joint ventures. Panel B displays summary statistics of 2,202 tracts that were auctioned in our sample period. On average, there are four bidders participating in each auction. We also highlight several interesting characteristics of tracts that represent the common tract values: predicted revenues, net revenues, and presale values. The conversion of production flows into predicted discounted revenues is explained in detail by Hendricks et al. (2003). Net revenues, defined as the predicted discounted revenues minus drilling costs and royalty payments (Hendricks et al., 2003), serve as the tract's ex post value.[6] Note that net revenues can be negative, meaning that drilling does not guarantee a successful discovery and production of oil and gas. Moreover, net revenues may be unavailable for certain tracts when firms decide not to drill wells after winning the auction. To supplement missing revenue information for some tracts, we utilize presale values. Presale values are a fair market value for each tract computed by the U.S. Geological Survey (Hendricks et al., 1989).[7]

In panel A of table 2, we compare characteristics between joint and solo bidders. On average, joint bidders submit bids that are 2.4 times higher than those of solo bidders. An average consortium consists of 3.5 firms. Moving to panel B of table 2, we compare tracts won by joint bidders with those won by solo bidders. This analysis is crucial as more desirable and profitable tracts tend to attract more joint bidders. As expected, tracts won by joint ventures exhibit higher predicted revenues, net revenues, and presale values compared to those won by solo bidders. The average winning bid for tracts won by joint ventures is 2.7 times higher than that for solo-won tracts. Moreover, joint winners faced more fierce competition, where tracts won by joint bidders had an average of 4.3 auction participants per auction. In contrast, tracts won by solo firms had an average of 3.1 participants. These descriptive statistics highlight that joint ventures place higher bids than solo bidders, and the tracts they enter and win differ in terms of their tract values.

[6] A fixed proportion of revenues is paid to the government as royalty payments where the royalty rate is $1/6$ in our sample. For more information on how predicted revenues and drilling costs are computed, see section 4 of Hendricks et al. (2003).

[7] The presale values are employed by the Department of Interior to assess the winning bid (Hendricks et al., 1989).

Table 1: Summary Statistics for All Observations

Panel A:	Bid-Level Statistics				
	N	Mean	SD	Min	Max
Bid	8054	9678.4	18262.6	0.181	304192.8
Joint	8054	0.509	0.5	0	1
Panel B:	**Tract-Level Statistics**				
	N	Mean	SD	Min	Max
Winning Bid	2202	12522.5	23717.7	2.3	304192.8
Mean Bid	2202	6159.1	11404.2	2.3	178918.3
Number of Bids	2202	3.7	3.3	1	18
Predicted Revenue	1612	28189.9	68303.6	0	806000
Net Revenue	1612	12753.1	45823.1	-39316.7	591766.7
Presale Value	945	4712.9	8933.1	53.1	80344.2

Note. The table suggests descriptive statistics for all observations at the bid and tract levels. All monetary values, such as bids, presale values, predicted revenues, and net revenues, are reported in thousands of dollars.

3 Research Design

We first provide a reduced-form analysis to describe the differences in bidding strategies or bid levels between joint and solo bidders in the auction game. Under the assumption that observed bids represent equilibrium bids, comparing the bid levels of the two types of bidders allows us to understand the overall impact of consortium formation, including the winner's curse effect.

Our baseline specification to analyze the effect of joint bidding on bids is:

$$\ln B_{it} = \beta \text{Joint}_{it} + \mathbf{X}_{it}'\alpha + \epsilon_{it}, \tag{1}$$

where $i = 1, 2, \cdots, N_t$ denotes a participant (either joint or solo firm) who offered a bid B_{it} in auction $t = 1, 2, \cdots, T$. Each observation represents a bid and includes information about the companies involved in the bid, either as a joint venture or a solo firm. Our key regressor, Joint_{it}, is a binary variable indicating whether the bid was submitted by a joint venture or not. We also include a vector of control variables denoted as $\mathbf{X}_{it}$: the number of bids, predicted revenues, drilling costs, presale values, the time taken to drill since the sale date, the time taken to produce oil or gas since the first spud date, whether a whole or portion of the block was auctioned, tract type (wildcat, development, or drainage), tract size, the distance between the auctioned tract and the closest tract won by bidder i in the past, and state and year fixed effects.

Table 2: Summary Statistics: Comparison of Joint and Solo Bidders

Panel A:		Bid-Level				
		N	Mean	SD	Min	Max
Joint	Bid	4102	13540.5	22384.9	21.9	304192.8
	N(Firms) in a JV	4102	4.2	1.8	2	13
Solo	Bid	3952	5669.7	11319.2	0.2	142110.1
Panel B:		**Tract-Level**				
		N	Mean	SD	Min	Max
Joint	Winning Bid	1029	18904	30152.9	21.9	304192.8
	Mean Bid	1029	9292.6	14538.7	21.9	178918.3
	Number of Bids	1029	4.3	3.5	1	18
	Predicted Revenue	804	30904.5	73077.7	0	806000
	Net Revenue	804	13833.1	49859.9	-39316.7	591766.7
	Presale Value	617	5697.5	10264.3	53.1	80344.2
Solo	Winning Bid	1173	6924.4	13849.5	2.3	142110.1
	Mean Bid	1173	3410.2	6531.3	2.3	99500.3
	Number of Bids	1173	3.1	2.9	1	16
	Predicted Revenue	808	25488.8	63126	0	474000
	Net Revenue	808	11678.5	41421.1	-36753.6	326600
	Presale Value	328	2860.8	5160.8	53.8	51341

Note. The table compares descriptive statistics between joint and solo bidders at the bid and tract levels. All monetary values, such as bids, presale values, predicted revenues, and net revenues, are reported in thousands of dollars.

The error term is denoted by ϵ_{it}. Standard errors are clustered at the saledate-area level.[8]

We expect joint ventures to submit higher bids compared to solo bidders, implying a positive coefficient, $\beta > 0$. However, there are two potential sources of endogeneity in the joint bidding decision: unobserved tract and firm heterogeneities. Firms may strategically form joint ventures to target more profitable tracts, introducing potential endogeneity in the joint bidding decision. To address this endogeneity problem, we control for ex post net revenues (Hendricks et al., 2003) and presale values (Hendricks et al., 1989), and the number of joint and solo bidders (Campo et al., 2003). By incorporating ex post net revenues and presale values, which reflect the true common values of tracts, we can account for the impact of tract heterogeneity. Moreover, controlling for the number of bids helps us capture variations in tract

[8]As discussed in the auction mechanism, multiple tracts were sold on a specific sale date. Therefore, we cluster standard errors at the saledate-area level to address potential dependence within these groups.

values, as more bidders, particularly consortia, typically participate in auctions for more valuable tracts.

Even after accounting for tract heterogeneity, joint bidding decisions can still suffer from unobserved bidder heterogeneity. Companies with inferior information or limited budgets tend to submit lower bids and are more likely to form joint ventures. Since information quality and budgets are not observable, the effect of joint bidding may be biased downward. To tackle the second source of endogeneity, we introduce a novel instrument: the proximity of the actual bidders' office addresses. Additionally, we propose another instrument, the historical occurrence of joint ventures among the actual bidders on the auctioned tract, to supplement our analysis. By leveraging these instruments, we aim to mitigate a potential downward bias on the effect of joint bidding on bid amounts.

We extend the analysis by categorizing joint and solo bidders into mutually exclusive and exhaustive groups, in addition to the baseline specification (1). Joint ventures are classified based on whether they consist exclusively of large firms, involve at least one fringe firm along with large firms, or consist solely of fringe firms. Likewise, solo bidders are categorized as either large solo firms or fringe solo firms. We follow the literature (Hendricks and Porter, 1992; Hendricks et al., 2003; Hendricks et al., 2008) and define 28 firms as large firms.[9] Therefore, we introduce the following specification that analyzes the effect of different types of joint ventures on bid amounts relative to large solo firms:

$$\ln B_{it} = \beta_1 \mathrm{LL}_{it} + \beta_2 \mathrm{LF}_{it} + \beta_3 \mathrm{FF}_{it} + \beta_4 \mathrm{F}_{it} + \mathbf{X}'_{it}\alpha + \epsilon_{it}, \tag{2}$$

where LL_{it}, LF_{it}, FF_{it}, and F_{it} are binary variables indicating whether the bid, B_{it}, was submitted by a large-exclusive consortium, a large-fringe consortium, a fringe-exclusive consortium, or a fringe solo firm, respectively. The baseline group consists of large solo firms. We include the same set of control variables, $\mathbf{X}_{it}$, as in the baseline specification (1). We continue to cluster the standard errors at the saledate-area level, as before.

We employ such categorization for two main reasons. First, the formation of joint ventures may be driven by different incentives across large and fringe firms. Large firms typically possess better knowledge or expertise compared to fringe firms. Large-

[9]The list of large firms includes Standard Oil of California, Standard Oil of Indiana, Shell, Gulf, Exxon, Union Oil of California, Phillips, Sun, Forest, Murphy, Texaco, Mobil, Tenneco, General American, Superior, SNG, Pennzoil, Signal, LaLand, Hess, Cabot, Kerr, Marathon, Felmont, ARCO, Cities, Getty, and Continental.

large joint ventures offer advantages such as access to more information, reduced competition, and lower risk (Hendricks and Porter, 1992). By contrast, Hendricks and Porter (1992) suggests that joint ventures between large and fringe firms may primarily arise due to budget constraints, where large firms exchange their knowledge and expertise for fringe firms' capital without revealing much of their information to potential large competitors. Second, it is empirically important to examine whether joint ventures submit higher bids even when compared to large solo firms. By comparing the bidding behavior of large solo firms with various categories of joint ventures, we can gain a more comprehensive understanding of how joint bidding strategies differ from solo ones.

Based on findings from previous studies, we anticipate that consortia involving large firms would submit bids of greater value than large solo firms, implying positive coefficients $\beta_1 > 0$ and $\beta_2 > 0$. Furthermore, we expect that, on average, large solo firms would place higher bids than fringe solo firms, indicating a negative coefficient, $\beta_3 < 0$. However, it remains unclear how fringe-fringe consortia would bid in comparison to large solo firms.

Considering that fringe firms constitute only 8% of the bids in our sample, we narrow our focus to the bidding behavior of large firms. Consequently, we refine the sample to include bids from large-large joint ventures, large-fringe joint ventures, and large solo firms. This refined specification is as follows:

$$\ln B_{it} = \beta_1 \mathrm{LL}_{it} + \beta_2 \mathrm{LF}_{it} + \mathbf{X}_{it}'\alpha + \epsilon_{it}. \tag{3}$$

The baseline group consists of large solo firms. We retain the same set of control variables, $\mathbf{X}_{it}$ as in the baseline specification (1), and we cluster the standard errors at the saledate-area level. We maintain our expectation that consortia involving large firms offer greater bids than large solo firms, implying positive coefficients $\beta_1 > 0$ and $\beta_2 > 0$.

In our final analysis using the reduced-form approach, we shift our focus from estimating the impact of joint bidding on individual bids, which has been discussed thus far. Instead, we explore the impact of competition and bidder structure on average bids, as it provides valuable insights into the relationship between joint bidding and the level of competition. Examining the effect of forming a joint venture presents challenges due to the bidirectional relationship between collusion formation and the competition level. For example, if joint ventures result in higher returns for firms, the entry rates and composition of joint and solo bidders in auctions are likely to adjust accordingly (Hendricks and Porter, 1992). Conversely, if firms anticipate high competition in an auction, they may form joint ventures to reduce the number of competitors and increase their chances of winning. It implies that the level of competition itself is endogenously determined, although we have so far controlled for it for specifications (1) - (3). Moreover, changes in the competition level induced by joint bidding impact all auction participants, which makes the estimation of the effect on individual bids even more complicated.

To gain a better understanding of how joint bidding, and consequently the number of joint bidders, affects bids, we investigate how a change in the composition of bidder types, characterized by the number of joint and solo bidders, influences bidding behavior across all auction participants given an overall competition level as a starting point. Consider a hypothetical average bidder for tract t. Then, the reduced-form relationship between the bidder structure and the average bid in auction $t = 1, 2, \cdots, T$ can be expressed as

$$\ln \overline{B}_t = \rho_1 \text{NumJoint}_t + \rho_2 \text{NumBid}_t + \mathbf{X}_t' \eta + u_t, \tag{4}$$

where $i = 1, 2, \cdots, N_t$ represents a bidder who submitted bid B_{it} in auction t, and $\overline{B}_t = N_t^{-1} \sum_{i=1}^{N_t} B_{it}$ is the mean bid in auction t. NumBid$_t$ denotes the total number of bids submitted in auction t, indicating the overall competition level. We decompose the competition level into two components: the number of joint bidders (NumJoint$_t$) and the number of solo bidders (NumSolo$_t$). This distinction is made because the effect of an additional joint bidder may differ from that of an additional solo bidder, and it thus accounts for the bidder structure given the overall competition level. In this specification, our observations are at the tract level. We also include a vector of control variables, denoted as $\mathbf{X}_t$, which captures tract characteristics such as predicted revenues, drilling costs, presale values, the time taken to drill since the sale date, the time taken to produce oil or gas since the first spud date, whether a whole or portion of the block was auctioned, tract type (wildcat, development, or drainage), tract size, the distance between the auctioned tract and the closest tract previously won by bidder i, and state and year fixed effects. The error term is denoted by u_t. Standard errors are clustered at the saledate-area level.

The main hypothesis for this specification is that having one more joint venture (and thereby one less solo firm) in the bidder structure leads to higher average bids at a given overall competition level. Alternatively, average bidders tend to submit higher bids when the ratio of joint to solo bidders increases under a given overall competition level. Therefore, we test whether $\rho_1 > 0$.

However, the competition levels also face endogeneity issues due to unobserved heterogeneities across tracts and firms. Similar to specifications (1) - (3), more valuable tracts tend to attract more bidders, introducing potential endogeneity in both the level of competition and the composition of joint and solo bidders within an auction. To address this endogeneity problem, we control for ex post net revenues (Hendricks et al., 2003) and presale values (Hendricks et al., 1989) as before. By incorporating these variables that reflect the true common values of tracts, we can account for the impact of tract heterogeneity.

Nevertheless, even after accounting for tract heterogeneity, the decisions surrounding joint bidding and the resulting number of joint bidders may still be influenced by unobserved heterogeneity among bidders. Companies with limited budgets or inferior information tend to submit lower bids and are more inclined to form joint ventures. Since both information quality and budget constraints are not observable, the effect of joint bidding may be biased downwards. Consequently, the number of joint bidders in specification (4) may also be subject to a downward bias due to this joint venture formation. In contrast, the direction of a bias is unclear for the effect of the overall competition level because the overall competition level contains both joint and solo components. To tackle this type of endogeneity, we utilize average proximity and history instruments within each auction for the number of joint bidders. Furthermore, we employ the number of potential bidders (Hendricks et al., 2003) as an instrument for the total number of bids.

Lastly, we present additional specifications in appendix 5 that examine the reduced-form relationship between the competition level and average bids (appendix A) as well as winning bids (appendix B). In both sections of the appendix, we use the number of joint bidders and the number of solo bidders as key regressors rather than controlling for the overall competition level. This approach allows us to test a hypothesis that the entry of an additional joint bidder has a larger impact on increasing average and winning bids compared to that of an additional solo bidder. We further explore how many solo bidders exiting an auction can be compensated for by the entry of a joint bidder in terms of average and winning bids.

3.1 Instruments Construction

Our novel instrument, the proximity of actual bidders' office addresses, is devised based on the idea that firms located near each other are more inclined to form joint ventures due to lower transaction costs.[10] To construct this instrument, we analyze lease contracts within the study period and identify each firm's office address up to the five-digit zip-code level. We assume that actual bidders of a tract are potential collaboration partners sought by firms prior to participating in the auction. As the list of actual bidders varies across tracts, the instrument is tract-varying (time-varying). The instrument satisfies the relevance restriction as nearby firms are more likely to form a consortium due to lower transaction costs. The exclusion restriction also holds since the closeness of firms' office addresses may affect bid amounts only through their joint bidding decision.

To illustrate, consider an auction has two actual bidders as in figure 1: P_J and P_S. Bidder P_J forms a consortium consisting of four participants: P_{J1}, P_{J2}, P_{J3}, and P_{J4}. Bidder P_S is a solo bidder. In terms of their office locations, P_S and P_{J1} are located in county C_1, P_{J2} is in county C_2, and P_{J3} and P_{J4} are in county C_3. To construct our instrument, we assign a value of one if there is another actual bidder with an office in the same county as the bidder, or zero otherwise. For solo bidder P_S, we assign a value of 1 since it has another firm, namely P_{J1}, located nearby. It indicates the likelihood of forming a joint venture based on office proximity, even though P_S entered the auction individually without forming a consortium. Essentially, our instrument captures proximity-based collaboration tendency, even if a firm ultimately chooses not to exert joint bidding efforts.

In the case of the joint bidder, we calculate this binary value for each joint venture participant and then take an average of the values. For participant P_{J1}, we assign a value of 1 because P_{J1} and P_S are located in the same county, despite not forming a joint venture together. Participant P_{J2} is assigned a value of 0 as no other firms are situated in the same county. Both participants P_{J3} and P_{J4} are assigned a value of 1 since they are located in the same county and indeed formed a joint venture together. Therefore, by averaging the four values of the consortium participants, we assign a value of $(1 + 0 + 1 + 1)/4 = 3/4$ to the instrument of joint bidder P_J. This averaging process captures the collective likelihood of joint venture formation of the consortium participants.

We also present the historical occurrence of joint ventures among actual bidders as another instrument. We expect that firms would prefer to continue partnering with their previous collaborators to some extent, as switching partnerships frequently incurs costs, including the search process itself.[11] Similar to the first instrument, we

[10]Given our study period from 1954 to 1974, communication costs could have played a more significant role than they do today when seeking a partner.

[11]At some point, however, a firm may strategically shift alliances as it may "not wish to share too

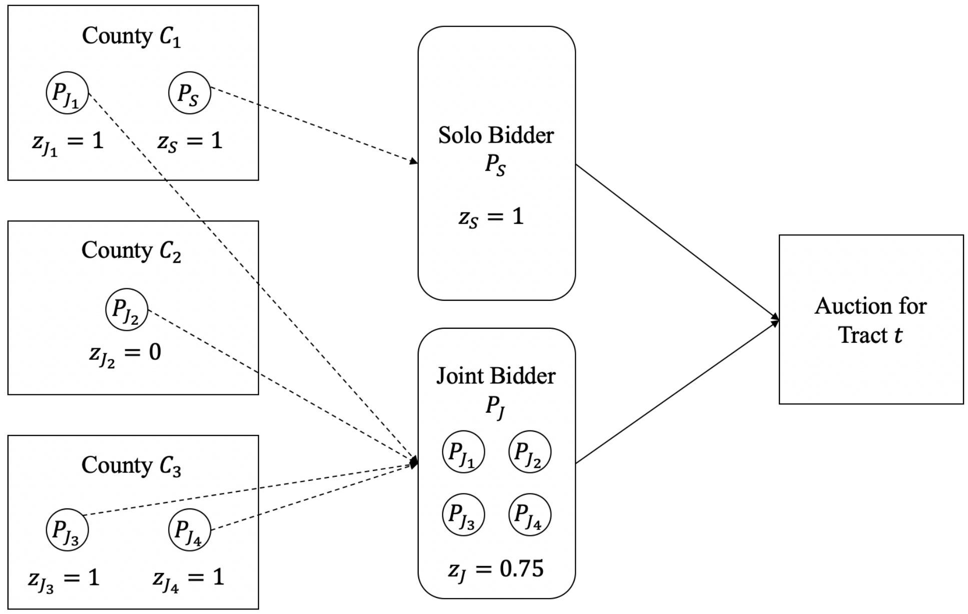

Figure 1: Construction of the Proximity Instrument

assume that actual bidders are potential partners for a given tract, and thus the instrument varies across tracts by construction. For a solo bidder, we assign a value of one if it had formed a consortium with any other participating firms in previous periods, or zero otherwise. For a joint bidder, we assign this binary value for each component of the joint venture and average these values. The instrument provides an overall measure of the historical partnership tendency.

Lastly, we identify the list of potential bidders for tract t based on the geographic coordinates of the tract (Hendricks et al., 2003) to utilize it as an instrument for the overall competition level. A neighborhood of tract t is defined to contain all tracts whose geographic coordinates are within 0.1158 degrees of longitude and 0.1012 degrees of latitude of tract t, and that were available for sale before the sale date of tract t (Hendricks et al., 2003). Actual bidders of tract t or the neighborhood tracts are all considered potential bidders since they are revealed to be auction participants. If a bid was submitted by a joint venture in the neighborhood tracts or tract t itself, then each joint venture member is counted towards the total number of potential bidders. The number of potential bidders would satisfy the relevance restriction as there are likely more actual bidders when a tract has more potential bidders. The instrument would also satisfy the exclusion restriction since the two determinants of defining a neighborhood, the geographic locations of tracts and the sale dates, are

much of its increasingly sophisticated information with any one partner" (Stuart, 1977).

exogenous variables and affect bid amounts only through the competition level.

4 Estimation Results

4.1 Effect of Joint Bidding on Bids

Table 3 presents the estimated impact of joint bidding on bid levels compared to solo bidding, using OLS and 2SLS estimation methods.[12] In column (1), we report the OLS results for specification (1), while columns (2) and (3) display the 2SLS results for the same specification. Joint bidders submit approximately 36% higher bids than solo bidders on average, according to column (1). The second stage of 2SLS in column (3) estimates an even larger effect, with joint ventures' bids being around 75% higher compared to solo bidders. This finding confirms that our two instruments effectively address a downward bias in estimating β in specification (1). The first stage results in column (2) show that both of our instruments are positively correlated with the joint binary variable. Additionally, we suggest statistics for underidentification, weak identification, and overidentification tests of the instruments in the last four rows of table 3 to assess the validity of the instruments.

Moving to column (4) of table 3, we present the OLS estimates for specification (2). Large-large and large-fringe consortia are predicted to offer higher bids compared to large solo firms by around 16% and 31%, respectively. However, it is worth noting that the OLS estimates of β_1 and β_2 in specification (2) may suffer from a downward bias, implying that the difference in bid amounts between large solo firms and consortia involving large firms could be even larger. These OLS results align with our prediction and convey a potential implication that consortia involving large firms may exhibit less concern regarding the winner's curse than large solo bidders. However, to examine this claim more precisely, a structural approach is required to measure the winner's curse. On the other hand, bids from fringe-fringe joint ventures are not expected to differ significantly from those of large solo firms. Fringe-exclusive consortia are predicted to bid substantially lower than large solo firms by roughly 73%, consistent with our prediction. Due to the limited number of instruments available to handle three different types of joint ventures, we do not perform an IV regression for specification (2).

Columns (5) - (8) provide OLS and 2SLS results for specification (3). According to column (5), large-exclusive joint ventures are expected to place bids approximately

[12] 2SLS estimation is employed according to Baum et al. (2003, 2007).

14% higher than large solo bidders, while large-fringe consortia tend to submit bids that are around 22% higher compared to the baseline group. Turning to the 2SLS results in column (8), we find even bigger effects where large-exclusive consortia offer approximately 86% higher bids relative to large solo firms. However, large-fringe consortia do not exhibit any significant difference against the baseline group due to their large standard errors. It can be attributed to our instruments not working effectively for large-fringe joint ventures. Specifically, the office-proximity-based instrument lacks statistical and economic significance when explaining large-fringe joint ventures in column (7). This is in stark contrast to its significance when explaining large-large consortia in column (6). It suggests that large firms consider office proximity when selecting another large firm as their partner, as they need to exchange sophisticated information about tract values. On the other hand, the office locations of fringe firms may not be as crucial when large firms choose them as partners, since their main purpose is to alleviate financial constraints (Hendricks and Porter, 1992). Moreover, the historical-occurrence instrument suggests a negative correlation with the large-fringe joint venture variable (column (7)) while showing a positive correlation with the large-exclusive binary variable (column (6)). In other words, large firms have a tendency to stick to their previous partner when the partner is another large firm, whereas they shift alliances frequently when partnering with small firms. It could be due to the high costs associated with switching partners when all participants of the joint ventures are large firms, given their size and information. In contrast, large firms could strategically change their partners as fringe firms do not possess much information about tract values but primarily provide financial assistance (Hendricks and Porter, 1992). Indeed, our 2SLS estimation for specification (3) does not pass the weak identification test using Kleibergen-Paap rk Wald F statistic.[13]

4.2 Effect of Bidder Structure and Competition on Mean Bids

Now we delve into table 4, which presents the estimated impact of the bidder structure and the competition level on average bids, as outlined in specification (4), using both OLS and 2SLS estimation methods. In columns (1) - (3), we estimate specification (4) without including the overall competition level, focusing solely on examining the effect of competition from joint ventures on the average bids for a tract. The results indicate that an additional joint bidder leads to an average bid increase of ap-

[13] The i.i.d. assumption does not hold in our case as we use cluster standard errors.

proximately 18% when using OLS in column (1). When utilizing 2SLS in column (3), this effect rises to around 36%. The estimates imply the presence of a competition effect, and the larger estimated effect of 2SLS compared to OLS suggests that our instruments successfully correct the downward bias. Column (2) presents the first stage of the 2SLS estimation, regressing the number of joint bidders on the average proximity and history instruments values. The last four rows provide statistics for underidentification, weak identification, and overidentification tests of the instruments, ensuring their validity.

Similarly, in columns (4) - (6), we estimate the specification without including the number of joint bidders, focusing solely on analyzing the effect of overall competition on average bids for a tract. The OLS estimate in column (4) indicates that an additional bidder leads to an approximately 13% increase in average bids. When employing the number of potential bidders as an instrument for the total number of bids in column (6), this effect rises to around 19%. It implies that the instrument corrects a downward bias in the competition effect. It is worth noting that the estimated effect of the overall competition level in column (6) is lower than that of the number of joint bidders in column (3), as the overall competition level includes both joint and solo bidders.

Columns (7) - (10) show estimation results for specification (4) with the inclusion of the two key regressors. The OLS estimates in column (7) suggest positive coefficients for both the number of joint ventures and the overall competition level, although the former is not statistically significant. The insignificance might be attributed to a downward bias in the effect of the number of joint bidders when using OLS. In addition, the effect of overall competition in column (7) might be overestimated as it would reflect the effect of the number of solo bidders after controlling for the number of joint bidders in the regression equation. Column (10) displays the second-stage results of 2SLS estimation, with columns (8) and (9) presenting the first-stage results for the number of joint bidders and the total competition level, respectively. According to column (10), controlling for the overall competition level, one more joint bidder (and hence one less solo bidder) leads to an around 30% increase in the average bid for an auction. In other words, the higher the proportion of joint bidders to solo bidders, the higher the average bids under the same overall competition level. This finding is intuitive, as joint bidders are likely to be more competitive than solo bidders, and bidder structures involving more competent bidders would yield higher average bids given an overall competition level. However, it is important to interpret these results cautiously since we are currently examining the tract-level impact by utilizing average bids as the dependent variable. To thoroughly investigate how joint bidding and changes in the competition level affect individual bids, a formal structural model is required, and the effect needs to be estimated accordingly.

5 Conclusion

The main contribution of this paper is to devise a novel instrument based on a new dataset about firms' office addresses at the time of writing a lease contract. Based on three instruments, we could correct a downward bias associated with joint bidding decisions as well as the number of joint bidders while endogenizing the overall competition level.

The first part of the study analyzes the effects of joint bidding on bid levels compared to solo bidding. The results show that joint bidders submit bids that are approximately 36% higher than solo bidders on average. The 2SLS estimation confirms this effect and suggests an even larger difference, with joint ventures' bids being around 75% higher than solo bidders. The instruments used in the analysis effectively address potential biases. We also examine different types of joint ventures and find that large-large and large-fringe consortia offer higher bids than large solo firms.

The second part of the study focuses on examining the effects of bidder structure and competition on average bids. The estimation results indicate that the entry of an additional joint bidder leads to an average bid increase of approximately 18% according to OLS estimation and around 36% according to 2SLS estimation, when not controlling for the overall competition level. When controlling for the overall competition level, the 2SLS estimates suggest that one more joint bidder (and thus one less solo bidder) is associated with an approximately 30% increase in the average bid. These findings suggest the presence of a competition effect, with a higher proportion of joint bidders inducing higher average bids.

In summary, our analysis indicates that joint bidders submit higher bids relative to solo bidders and that a higher proportion of joint bidders leads to an increase in average bids given an overall competition level. However, this approach has three limitations: Firstly, the reduced-form analysis only compares observed bids and does not provide insight into how different joint and solo bidders are in terms of their signal distributions, which contribute to variations in bidding strategies. Secondly, the reduced-form analysis does not explicitly measure and compare the level of the winner's curse between joint and solo bidders. While we can infer a potential reduction in the winner's curse effect in the case of joint bidding based on the higher bid values of joint bidders, a more rigorous examination is needed. Thirdly, the reduced-form approach for estimating the effect of bidder structure and competition on average bids at the tract level does not capture how the bidder structure and competition levels influence individual bids. To investigate the impact of joint venture formation on individual bids, considering the winner's curse effect and the competition effect, we need to develop a formal structural model and measure it accordingly. Therefore, to address these limitations and complement the reduced-form analysis, we will establish a formal structural model in the next version of this paper to describe how each type of bidder determines their bidding strategies, taking into account the joint signal distributions. We then propose the measure for the winner's curse and identification strategies to estimate the level of the winner's curse and the bid function. Our ultimate objective with the structural analysis is to empirically determine the combined effects of the winner's curse and reduced competition, which is currently in progress and under development.

Table 3: Effect of Joint Bidding on Bids

	OLS	2SLS		OLS	OLS	2SLS		
		First Stage	Second			First Stage		Second
		Joint	Stage			Large-Large	Large-Fringe	Stage
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Joint	0.307***		0.562***					
	(0.0554)		(0.141)					
Large-Large				0.147***	0.134***			0.619***
				(0.0478)	(0.0454)			(0.182)
Large-Fringe				0.272***	0.197***			1.655
				(0.0669)	(0.0642)			(1.137)
Fringe-Fringe				0.194				
				(0.183)				
Fringe				-1.315***				
				(0.211)				
Proximity		0.221***				0.195***	0.0372	
		(0.0349)				(0.0212)	(0.0301)	
History		0.291***				0.397***	-0.108***	
		(0.0399)				(0.0301)	(0.0395)	
Observations	7,325	7,061	7,061	7,325	6,750	6,738	6,738	6,738
R-squared	0.535		0.493	0.553	0.504			0.409
KP LM statistic			43.134					2.920
CD F statistic			374.477					16.131
KP F statistic			121.261					1.746
J statistic			3.313					

Note. The table reports OLS and 2SLS estimates of specifications (1) - (3). The 2SLS estimation is employed according to Baum et al. (2003). Columns (1) - (3) display results for specification (1), column (4) for specification (2), and columns (5) - (8) for specification (3). The last four rows of the table contain statistics for underidentification, weak identification, and overidentification tests of the instruments used. Standard errors are clustered at the saledate-area level.

Table 4: Effect of Bidder Structure and Competition on Mean Bids

	OLS	2SLS		OLS	2SLS		OLS	2SLS		
		First Stage	Second		First Stage	Second		First Stage		Second
		NumJoint	Stage		NumBid	Stage		NumJoint	NumBid	Stage
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
NumJoint	0.164***		0.311***				0.0327			0.261**
	(0.0181)		(0.0333)				(0.0242)			(0.132)
NumBid				0.125***		0.176***	0.106***			0.0247
				(0.0109)		(0.0322)	(0.0181)			(0.0922)
Proximity		1.268***						1.089***	2.533***	
		(0.164)						(0.152)	(0.215)	
History		1.262***						1.177***	0.658**	
		(0.219)						(0.219)	(0.319)	
NumPotential					0.0851***			0.0442***	0.0631***	
					(0.0135)			(0.00792)	(0.0124)	
Observations	1,745	1,733	1,733	1,745	1,745	1,745	1,745	1,733	1,733	1,733
R-squared	0.679		0.644	0.690		0.680	0.691			0.658
KP LM statistic			55.599			34.605				21.177
CD F statistic			177.559			172.597				22.972
KP F statistic			116.608			40.002				12.469
J statistic			0.060							0.858

Note. The table reports OLS and 2SLS estimates of specification (4). The 2SLS estimation is employed according to Baum et al. (2003). Columns (1) - (3) display estimation results for specification (4) without controlling for the total number of bids. Columns (4) - (6) exhibit results for the specification without including the number of joint bidders. Columns (7) - (10) estimate specification (4) with the inclusion of both the number of joint bidders and the total number of bids. For columns (8) - (10), both the number of joint bidders and the total number of bids are instrumented based on 2SLS. The last four rows of the table contain statistics for underidentification, weak identification, and overidentification tests of the instruments used. Standard errors are clustered at the saledate-area level.

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A Effect of Competition on Mean Bids

In section 3, we examined how a change in the composition of bidder types affects bid levels given an overall competition level. Another intriguing investigation involves the decomposition of the competition level into the number of joint bidders (NumJoint_t) and that of solo firms (NumSolo_t) and incorporates them in the regression equation. This distinction is made because the effect of an additional joint bidder may differ from that of an additional solo bidder. Then, the reduced-form relationship between the competition level and the average bid in auction $t = 1, 2, \cdots, T$ is

$$\ln \overline{B}_t = \delta_1 \text{NumJoint}_t + \delta_2 \text{NumSolo}_t + \mathbf{X}_t' \gamma + u_t, \tag{5}$$

where $i = 1, 2, \cdots, N_t$ represents a bidder who submitted bid B_{it} in auction t, and $\overline{B}_t = N_t^{-1} \sum_{i=1}^{N_t} B_{it}$ is the mean bid in auction t. We include a vector of control variables $\mathbf{X}_t$ as in specification (4) to capture tract characteristics. Standard errors are clustered at the saledate-area level.

We anticipate that the presence of an additional bidder, regardless of type (joint or solo), would lead to higher winning bids in auctions ("competition effect"), implying positive coefficients, $\delta_1 > 0$ and $\delta_2 > 0$. Furthermore, joint bidders are likely to be stronger competitors compared to solo bidders, so an additional joint bidder would have a greater impact on raising the average bid than an additional solo bidder. Thus, we expect $\delta_1 > \delta_2 > 0$. One interesting question is how many solo bidders the entry of a joint bidder can compensate for in terms of the average bid. To illustrate, suppose a joint bidder enters an auction, and k solo bidders exit the auction. Then, the combined effect of such a change on the average bid in the auction would be $\delta_1 - k \cdot \delta_2$, where $k = 1, 2, \cdots$. This could alternatively be interpreted as the effect of k solo bidders forming a consortium on the average bid.

Similar to specification (4), the competition level faces endogeneity problems due to unobserved tract and firm heterogeneities. Specifically, the impact of the number of joint bidders may be subject to a downward bias, whereas the effect of competition from solo bidders may be subject to an upward bias. To account for the unobserved tract heterogeneity, we control for ex post net revenues (Hendricks et al., 2003) and presale values (Hendricks et al., 1989) as before. To address the unobserved firm heterogeneity, we use average proximity and history instruments for the number of joint bidders and, in certain cases, the number of solo bidders.

Table 5 provides OLS and 2SLS estimation results for specification (5). Note that the last four rows provide statistics for underidentification, weak identification, and overidentification tests of the instruments, ensuring their validity. In column (1), we find that the average bid in an auction increases by 15% with the entry of an additional joint bidder, and by 11% if the new entrant is a solo bidder. Columns (2) - (3) display 2SLS results for the specification, assuming that the number of solo bidders is exogenous and instrumenting only the number of joint bidders. The first stage in column (2) reveals the results of regressing the number of joint bidders on the number of solo firms and the two instruments. Column (3) shows that an additional joint bidder in an auction has an even greater impact on the average bid, approximately 34%, while an additional solo bidder is associated with a modest 5% increase. Combining the OLS results from column (1) and the 2SLS results from column (3), we find that estimates of δ_1 are greater than those of δ_2, implying that the entry of a stronger competitor induces a higher competition effect.

Furthermore, based on the 2SLS estimation results in column (3), the entry of one additional joint venture can compensate for the reduction of up to five solo bidders in an auction. In other words, if five or fewer bidders form a consortium in an auction, all else equal, the average bid would either remain the same or increase.[14] As before, it is crucial to interpret these findings with caution as we are currently analyzing the impact at the tract level using average bids as the dependent variable. To comprehensively investigate the effects of joint bidding and changes in the competition level on individual bids, a formal structural model is required.

Columns (4) - (6) of table 5 consider both the number of joint ventures and the number of solo firms as endogenous variables and employ the two average values of the instruments in the 2SLS estimation. We find even bigger competition effects for additional joint bidders, where each additional joint bidder translates into a rise in the average bid by about 35%. However, the effect of an additional solo bidder is not statistically significant, mainly due to its large standard errors, although the sign of the effect remains positive. It may be because our instruments were devised to account for the incentives behind forming a joint venture in terms of office proximity and history of alliances, effectively explaining the number of joint bidders. By contrast, these instruments may not adequately explain how solo bidders enter an auction or how the number of solo bidders changes. Assuming both the numbers of joint and solo bidders as endogenous variables in column (6), the Kleibergen-Paap rk Wald F statistic of our 2SLS estimation has relatively low values.[15]

[14]It is worth noting that, according to the summary statistics in table 2, the average number of firms in a joint venture is 3.5, which is lower than the estimated threshold of five.

[15]The first stage regression in column (5) demonstrates that the average history tendency of bidders in an auction is negatively correlated with the number of solo bidders in that auction.

In summary, the entry of an additional joint bidder is associated with higher average bids.

B Effect of Competition on Winning Bids

In addition to the reduced-form analysis of the competition level and the average bid in appendix A, we investigate how joint bidding, and consequently the number of joint bidders, affects winning bids. This may be a question of interest to auctioneers as what they care about would be the highest bid they receive in first-price auctions. Then, the reduced-form relationship between the competition level and the winning bid in auction $t = 1, 2, \cdots, T$ is

$$\ln W_t = \delta_1 \text{NumJoint}_t + \delta_2 \text{NumSolo}_t + \mathbf{X}_t' \gamma + u_t, \tag{6}$$

where $i = 1, 2, \cdots, N_t$ represents a bidder who submitted bid B_{it} in auction t, and $W_t = \max_{i=1}^{N_t} \mathrm{B}_{it}$ is the winning bid in auction t. As in specification (5), we decompose the competition level into two components: the number of joint bidders (NumJoint_t) and the number of solo bidders (NumSolo_t). We also include a vector of control variables as before, denoted as $\mathbf{X}_t$, which captures tract characteristics. Standard errors are clustered at the saledate-area level.

Our hypotheses for this specification align with those for specification (5). First, we anticipate that the presence of an additional bidder, regardless of type (joint or solo), would result in higher winning bids in auctions ("competition effect"), implying positive coefficients, $\delta_1 > 0$ and $\delta_2 > 0$. Second, since joint bidders tend to be stronger competitors than solo bidders, an additional joint bidder would have a greater impact on raising the winning bid than an additional solo bidder. Thus, we expect $\delta_1 > \delta_2 > 0$. Third, we can examine how the entry of a joint bidder compensates for the exit of a certain number of solo bidders in terms of the winning bid. For instance, if a joint bidder enters the auction and k solo bidders exit, the combined effect on the winning bid would be $\delta_1 - k \cdot \delta_2$, where $k = 1, 2, \cdots$. This could alternatively be interpreted as the effect of k solo bidders forming a consortium on the winning bid.

Endogeneity problems arising from unobserved tract and firm heterogeneities are handled similarly to specification (5). In particular, the impact of the number of joint bidders may be subject to a downward bias, whereas that of solo bidders may suffer from an upward bias. To address unobserved tract heterogeneity, we control for ex post net revenues (Hendricks et al., 2003) and presale values (Hendricks et al., 1989) as before. To tackle unobserved firm heterogeneity, we use the proximity and history instruments of the winners as instruments.

The estimation results for specification (6) are suggested in table 6, which is qualitatively similar to the results in table 5. In columns (1) - (3), we estimate specification (6) without including the number of solo bidders, focusing solely on examining the effect of competition from joint ventures on the winning bids for a tract. The results indicate that an additional joint bidder leads to an approximately 29% increase in winning bids when using OLS in column (1). When employing 2SLS in column (3), this effect rises to around 74%. This implies the presence of a competition effect, and the larger estimated effect of 2SLS compared to OLS suggests that our instruments successfully correct for the downward bias. Similar to tables 3 and 4, the last four rows provide statistics for underidentification, weak identification, and overidentification tests of the instruments, ensuring their validity.

Columns (4) - (9) of table 6 present the estimated results for specification (6) with the inclusion of the number of solo bidders. In column (4), we find that the winning bid in an auction increases by 23% with the entry of an additional joint bidder, and by 25% if the new entrant is a solo bidder. The OLS estimates contradict our hypothesis that $\delta_1 > \delta_2 > 0$. However, this may be attributed to the downward bias in the impact of the number of joint bidders and the upward bias in that of solo bidders when estimating with OLS. To correct such biases, columns (5) - (6) suggest 2SLS results, assuming that the number of solo bidders is exogenous and instrumenting only the number of joint bidders. Column (6) shows that an additional joint bidder to an auction is associated with an approximately 62% increase in the winning bid, while an additional solo bidder is associated with a modest 13% increase. Thus, we find that the estimate of δ_1 is greater than that of δ_2, implying that the entry of a stronger competitor induces a higher competition effect. Furthermore, according to the 2SLS estimation results in column (6), the entry of one additional joint venture can compensate for the reduction of up to four solo bidders in an auction. In other words, if four or fewer bidders form a consortium in an auction, the winning bid would either remain the same or increase, all else equal.

Columns (7) - (9) of table 6 consider both the number of joint ventures and the number of solo firms as endogenous variables and employ the two average values of the instruments in the 2SLS estimation. We find even bigger competition effects for additional joint bidders, where each additional joint bidder leads to a rise in the winning bid by about 69%. However, the entry of an additional solo bidder does not lead to any significant increase in the winning bid, despite the sign of the effect remaining positive. By construction, our instruments are designed to account for the incentives behind forming a joint venture and, therefore, may not well explain how solo bidders enter an auction or how the number of solo bidders changes. In fact, when instrumenting both the numbers of joint and solo bidders with the proximity and history instruments in column (9), our 2SLS estimation 6 fails the weak identification test using Kleibergen-Paap rk Wald F statistic.

To sum up, an additional joint bidder to an auction increases the winning bid for the tract, indicating that allowing joint bidding may result in a higher winning bid received by the auctioneer.

Table 5: Effect of Competition on Mean Bids

	OLS	2SLS		2SLS		
		First Stage	Second	First Stage		Second
		NumJoint	Stage	NumJoint	NumSolo	Stage
	(1)	(2)	(3)	(4)	(5)	(6)
NumJoint	0.139***		0.290***			0.301***
	(0.0153)		(0.0369)			(0.0521)
NumSolo	0.106***	0.271***	0.0502**			0.0231
	(0.0181)	(0.0524)	(0.0228)			(0.0938)
Proximity		0.855***		1.268***	1.520***	
		(0.176)		(0.164)	(0.183)	
History		1.393***		1.262***	-0.483***	
		(0.205)		(0.219)	(0.184)	
Observations	1,745	1,733	1,733	1,733	1,733	1,733
R-squared	0.691		0.656			0.650
KP LM statistic			54.780			21.188
CD F statistic			141.040			34.195
KP F statistic			92.869			18.440
J statistic			0.091			

Note. The table reports OLS and 2SLS estimates of specification (5). The 2SLS estimation is employed according to Baum et al. (2003). In columns (2) - (3), we employ 2SLS by instrumenting only the number of joint bidders, assuming that the number of solo bidders is exogenous. For columns (4) - (6), both the number of joint bidders and the number of solo bidders are instrumented using the average proximity and history instruments. The last four rows of the table contain statistics for underidentification, weak identification, and overidentification tests of the instruments used. Standard errors are clustered at the saledate-area level.

Table 6: Effect of Competition on Winning Bids

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	OLS	2SLS		OLS	2SLS		2SLS		
		First Stage	Second Stage		First Stage	Second Stage	First Stage		Second Stage
		NumJoint			NumJoint		NumJoint	NumSolo	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
NumJoint	0.258***		0.554***	0.206***		0.485***			0.524***
	(0.0258)		(0.0509)	(0.0200)		(0.0541)			(0.0858)
NumSolo				0.221***	0.265***	0.119***			0.0497
				(0.0222)	(0.0536)	(0.0321)			(0.123)
Proximity		1.181***			0.887***		1.181***	1.110***	
		(0.116)			(0.120)		(0.116)	(0.138)	
History		0.725***			0.743***		0.725***	-0.0672	
		(0.119)			(0.121)		(0.119)	(0.108)	
Observations	1,745	1,726	1,726	1,745	1,726	1,726	1,726	1,726	1,726
R-squared	0.677		0.567	0.714		0.625			0.595
KP LM statistic			48.867			50.880			15.908
CD F statistic			134.842			94.402			12.339
KP F statistic			98.305			86.510			9.476
J statistic			0.152			0.313			

Note. The table reports OLS and 2SLS estimates of specification (6). The 2SLS estimation is employed according to Baum et al. (2003). Results are displayed in columns (1) - (3) for specification (6) without controlling for the number of solo bidders. Columns (4) - (9) estimate specification (6) with the inclusion of the number of solo bidders. In columns (5) - (6), we employ 2SLS by instrumenting only the number of joint bidders, assuming that the number of solo bidders is exogenous. For columns (7) - (9), both the number of joint bidders and the number of solo bidders are instrumented using 2SLS. The last four rows of the table contain statistics for underidentification, weak identification, and overidentification tests of the instruments used. Standard errors are clustered at the saledate-area level.