Auctions with Positive Synergies: Experimental Evidence

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ABSTRACT

In a standard auction, bidders bid more aggressively when the number of bidders increases. However, Krishna and Rosenthal (1996, *Games and Economic Behavior*) show that when bidders have multiple-unit demand that generates positive synergies, bidders bid *less* aggressively as the number of bidders increases. The first objective of this paper is to offer experimental evidence on this seemingly counter-intuitive theoretical prediction. Following the model of Krishna and Rosenthal, we design a simultaneous second-price sealed-bid auction for two objects with two types of bidders: Single-object and multiple-object demand bidders. Our results show that bidders bid less aggressively with increased competition. The second objective is to investigate the effect of offering global bidders the option of bidding for both objects as a package as well as submitting individual bids for each object. Controlling for bidders' valuations, we find that offering this option to global bidders increases allocative efficiency and seller's revenue.

Keywords: Auction, Positive Synergies, Increased Competition, Package Bids.
JEL Classification: C91, D44

1 Introduction

When there are more bidders bidding for various objects in an auction, do bidders bid more or less aggressively? In a standard auction assuming independent private valuations, bidders bid more aggressively (Vickrey, 1961; Kagel and Levin, 1993; Battalio, et al, 1990). However, when bidders have demand for multiple objects with positive synergies, Krishna and Rosenthal (1996) show that bidders bid *less* aggressively with more bidders. Positive synergies are present when the value of a package exceeds the summed value of the individual objects in that package. Positive synergies may arise due to economies of scale, complementarities, cost savings due to a firm's geographical advantage, specialization, etc.

The presence of positive synergies in a multiple-object auction brings up another important question: Should sellers sell the objects separately or offer them as a package? By allowing package bids, sellers could capture some of the synergies from the bidders' valuation and hence increase revenue. Palfrey (1985), in a laboratory experiment, finds that packaging is inefficient in allocating individual objects to the bidder with the highest valuation. Cantillon and Pesendorfer (2006) in an empirical study of the London bus routes auction conclude that the social benefits of allowing combinatorial bidding on various combinations of bus routes are ambiguous. Bykowsky, et al (2000) warn that bidders may incur financial losses due to "mutually destructive bidding." Rothkopf, et al (1998) point out two disadvantages to bundling objects: a "threshold" problem and the computational difficulty involved in generating the revenue-maximizing combination for the package. The "threshold" problem recognizes that single-object bidders with high stand-alone private values may not be able to submit a coordinated bid that is higher than a bid submitted by a multiple-object bidder with lower stand-alone private values.

The purpose of this study is to offer experimental tests of the two questions above: When bidders have multiple-object demand with positive synergies (1) Do bidders bid more or less aggressively when there are more bidders? (2) Should sellers sell the objects separately or as a package? We utilize the model of Krishna and Rosenthal (1996) to design a simultaneous second-price sealed-bid auction. The auction game in our experiment involves two objects and two types of bidders: Local bidders with single-object demand and global bidders with multiple-object demand with positive synergies. To address the first question, we conduct treatments with different number of bidders. To address the second question, we conduct treatments in which the bidders are given the option of bidding for the entire package as well as bidding for individual objects.

Our results confirm the theoretical prediction of Krishna and Rosenthal (1996) that global bidders bid *less* aggressively when there are more rival bidders. We also find that allocative efficiency and sellers' revenue are higher when the bidders are given the option of bidding for the entire package of objects as well as bidding for individual objects. In addition, our results indicate that local bidders bid higher than their valuations while global bidders bid less than their predicted levels. Our results further indicate an asymmetry in the bidding behavior of high- and low-private value bidders. Compared to the high-private value bidders, low-private value bidders submit bids with larger positive differences from their private values.

Our paper contributes to the existing experimental literature on the effect of number of bidders by extending the analysis from bidders with single-object demand to bidders with multiple-object demand that generates positive synergies. Our findings could be useful in the optimal design of auctions for selling multiple complementary objects.

Our experimental setting is relevant to many business applications. Situations where bidders have multiple-unit demand and have increasing marginal returns for multiple objects are rapidly becoming commonplace. Examples include airline landing slot auctions (Rassenti, et al, 1982), Federal Communications Commission spectrum auction (Krishna and Rosenthal, 1996; Milgrom, 2000), procurement auctions (Katok and Roth, 2004) and farmland auctions (Colwell and Yavas, 1994).

Our paper is structured as follows. Section 2 reviews the relevant literature relating to bidding strategy, seller's strategy and previous experiments on multi-object auction with synergies. Section 3 summarizes the theoretical predictions outlined in Krishna and Rosenthal (1996). These predictions form part of the hypotheses in our analysis. Section 4 describes our experimental design. Section 5 presents the experimental results. Section 6 concludes.

2 Literature Review

2.1 The “Exposure” Problem

When a bidder has multiple-object demand and gains positive synergies from obtaining these objects in one package, one of the bidder’s foremost considerations would be the “exposure” problem. The nature of the “exposure” problem is different depending on whether the objects are interchangeable (U.S. treasury bills, initial public offerings of stocks shares and transferable pollution permits) or whether the objects are distinct (farmland, timber, off-shore oil leases, and bus-routes). In the former case, the literature is concerned with demand-reduction behavior in uniform-price auction (Kagel and Levin, 2001, 2005; List and Lucking-Reiley, 2000; Engelbrecht-Wiggans, et al, 2006).

Our paper focuses on the latter case. When the objects are sold separately, bidders may bid above their stand-alone value for the individual object. This course of action has two effects. The first effect increases bidders’ chances of winning all the desired objects in the package. Palfrey (1985) conducts an experiment selling objects in packages using a first-price sealed-bid auction. In his study, no synergies are present in the package; the value of a package is simply the sum of the stand-alone values of individual objects. Yet, he finds that bidders are bidding higher than the summed value of the individual objects in the package.

The second effect exposes bidders to financial losses if they do not win all the desired objects. The magnitude of the financial losses is correlated to the amount of over-bidding above the stand-alone value of the individual objects. Depending on factors such as bidders’ risk preferences, the severity of potential losses, and bidders’ avoidance of the "exposure" problem, bidders may not bid aggressively and at the extreme, may not participate in the bidding (Bykowsky, el at, 2000; Kagel and Levin, 2005). Kagel and Levin (2005) term this a "behavioral" force and the responsiveness of bidders to this problem is akin to "loss aversion." The bidders' behavior has implications for efficiency and revenue maximization. The objects may not be allocated to the bidder with the highest value for the package because the bidder is not willing to bid above the stand-alone value of the individual object. In addition, when bidders bid less aggressively, sellers are not able to capture a larger portion of the synergies from the bidders.

In the case of a second-price sealed-bid auction, the highest bidder wins the object and pays the highest losing bid. When there are more competitors, the price payable by the winning bidder, vis-à-vis the highest losing bid, is correspondingly higher. As a result, bidders incur potentially larger losses when they bid above the stand-alone value. Krishna and Rosenthal (1996) loosely term this as the "price-effect". We refer to the first of our research questions: Do bidders bid more or less aggressively when there are more bidders? Krishna and Rosenthal (1996) prove theoretically that bidders bid *less* aggressively. The intuitive explanation for this seemingly counter-intuitive result is that the "price-effect" is higher when there are more bidders. Hence, the increased probability of making losses leads to *less* aggressive bidding.

2.2 The Argument for Package Bidding[i]

When a seller has multiple objects to auction, the seller could: (i) sell the objects separately; (ii) sell the objects as packages (combinatorial[ii]); and (iii) sell the objects both

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[i] Our discussion of package bidding here is not exhaustive. We have narrowed our discussion to focus on issues related to the number of bidders and the option for package bidding. Issues like 'fitting' problems, 'coordination', auction rules covering stopping, activity and withdrawal rules, superadditive values versus subadditive values are important considerations when considering combinatorial auctions. (See Plott, 1987; Ledyard, et al, 1997; Bykowsky, 2000; Cramton, et al, 2006).

[ii] Cramton, et al (2006) define combinatorial auctions as auctions where bidders bid for combinations of objects, rather than for individual objects. [p. 1]. Rothkopf, et al (1998) define combinational bids synonymously to package bids. Bykowsky, et al (2000) define a "package bid" as an auction where bidders can submit bids for both the individual objects as well as combinations of objects [p. 208].

separately and as packages (combinational). Cantillon and Pesendorfer (2006) note that when synergies are present, a combinatorial bidding option is necessary for efficiency and optimality. Krishna and Rosenthal (1996) run a simulation and find that the simultaneous auction generates higher revenue for the seller than the combinational auction. Bykowsky, et al. (2000) explain that when individual objects are sold simultaneously, bidders may engage in "mutually destructive bidding" leading to financial losses. Hence, in some auctions, withdrawal rules are in place to permit bidders to withdraw their bids during the auction. Plott (1987), in his testbed experiments, finds evidence of destructive competitive behavior where an agent may strive to acquire key objects in other competitors' package.

In the literature, regardless of the auction form analyzed, there seems to be two central arguments. The first is that when there are a small number of bidders, bundling increases seller's revenue (Palfrey, 1983, 1985; Chakraborty, 1999). Selling objects in a package stimulates competition amongst the few bidders and thus raises revenue.

The second is that when the number of bidders bidding for the items is large, packaging objects creates inefficiencies and lowers revenue due to the "threshold" problem. When objects are sold separately, each object is sold to the highest bidder. When there are many bidders, the price paid is likely to be high because the distributions of values are correspondingly high. However, when the objects are packaged, the winning bidder may not have the highest valuation for each object in the package. As a result, the summed value of selling each object individually may be higher than the value of selling the objects in a package (Palfrey, 1985; Rothkopf, et al, 1998; Chakraborty, 1999; Bykowsky, et. al., 2000; Cantillon and Pesendorfer, 2006).

When bidders incur costs to participate in the auction, then according to the theoretical work by Chakraborty (2006), objects should be sold separately. The reasoning is that since competitive bidders self-select to participate in the auction, the competitive element induced by packaging objects would be rendered unnecessary.

In testbed experiments related to the FCC Spectrum auction, Ledyard, et al. (1987) and Plott (1987) find similar experimental results. When there are significant complementarities, allowing package bidding improves efficiency and revenue. Ledyard, et. al. (1987) conclude that in terms of mechanism performance, auctions that allow package bidding weakly dominate simultaneous auctions. They also find that simultaneous auctions weakly dominate sequential auctions.

2.3 Findings from Similar Experimental Studies

In this section, we review two experimental papers on auctions with synergies and highlight findings that are relevant to our study. Although the research questions are different, the experimental settings in Kagel and Levin (2005) and Isaac and James (2000) are similar to ours.

Kagel and Levin (2005) investigate the bidding behavior of a bidder with multiple-unit demand with synergies in a uniform-price auction. More specifically, they look at how a bidder would respond to the two counterbalancing forces of demand-reduction and superadditive gains. The predictions for equilibrium behavior are similar to those by Krishna and Rosenthal (1996). Two units are auctioned to two types of bidders. There are three or five local bidders (played by computers) with single-unit demand and one global bidder (played by human subjects) with two-unit demand. There are three key differences between our experimental designs. Firstly, ours is a discriminatory auction with no demand reduction pressures. Secondly, in our study both the local and global bidders are played by human subjects. We have one local bidder and either two or five global bidders for each object. Thirdly, the positive synergy in our experiment is a fixed, constant value common to all global bidders whereas the positive synergy in Kagel and Levin (2005) varies with the stand-alone value of the object.

In their sealed-bid auction treatment, Kagel and Levin (2005) find that bidders overbid if they have low values, consistently bid above their values if they have intermediate values and underbid if they have high values. When there are three local bidders, global bidders submit unequal bids for the two units. When there are five local bidders, global bidders submit equal bids for the two units. Efficiency is lower when there are three local bidders (91%-92%) compared to when there are five local bidders (94%). Revenue is lower when there are three local bidders (9%) compared to when there are five local bidders (11%).

Isaac and James (2000) test the demand-revealing properties of the Vickrey combinatorial auction. This is an extension of the standard Vickrey auction to a multiple-object goods auction, where synergies are obtained from packaging the objects. The payment rule for the Vickrey combinatorial auction is similar to that of a Vickrey-Groves mechanism. The winning bidder pays the total reported surplus of all the other bidders based on the alternative outcome in which the winning bidder is not a participant in the auction. Two objects are auctioned to three bidders who demand both objects. The authors compare performance between two auction formats: a simultaneous “two-bid” second-price sealed-bid auction and a Vickrey combinatorial auction. The bidder submits three bids in the Vickrey combinatorial auction: one bid for each object and one bid for both objects as a package. Within the Vickrey combinatorial auction, the authors have two treatments. In one, a bidder who wins both objects individually and not as a package does not obtain the synergies associated with winning both objects together. In the other, the bidder obtains synergies as long as they won both objects.

Isaac and James (2000) study differs substantially from ours in the distribution of the values for the package. In our study, all global bidders have the same common synergy value. In Isaac and James (2000), the bidders first draw the values for each object from a uniform distribution of (0,5). They subsequently draw another value for both objects as a package from a different uniform distribution of (0,10). From this draw, in one treatment, bidders’ value for the package is allowed to be less than the summed values of the individual objects (sub-additive synergies). In another treatment, bidders’ value for the package has to be greater than or equal to the summed values of the individual objects (super-additive synergies).

The authors find that bidders do not practice the dominant strategy of bidding their true values. In the Vickrey combinatorial auction, bidders bid close to their true values only about 50% of the time. Analyzing individual bidding behavior, the authors find that about 72% of the subjects are bidding their private values for the objects/package. In terms of efficiency, the Vickrey combination has an average efficiency of 96%. The simultaneous auction has an average efficiency of 91.5%. When bidders do not obtain synergies from winning both objects, the authors find that efficiencies in the simultaneous auction drop further. The average efficiency for the simultaneous auction is 84.5%, compared to 96.5% for the Vickrey combinatorial auction.

Our paper has a different experimental set up than Isaac and James (2000) and Kagel and Levin (2005). In Isaac and James (2000), the number of global bidders remains constant throughout the treatment as the primary objective is to test the demand-revelation effect of Vickrey combinatorial auction rather than the effect of increased competition on bidding. In Kagel and Levin (2005), there is one global bidder whereas we have multiple global bidders and we allow the number of global bidders to change across treatments. This enables us to test the theoretical prediction of Krishna and Rosenthal (1996) that global bidders bid less aggressively with increased competition. In addition, the local bidders in Kagel and Levin (2005) are played by computers that are programmed to bid their private values. In our study, the local bidders are played by human subjects.

3 Theoretical Predictions and Hypotheses

In this section, we summarize Krishna and Rosenthal (1996) predictions of equilibrium behavior in a simultaneous auction with positive synergies. We first describe their auction set-up and subsequently review predicted equilibrium behavior that is relevant to our experimental design.

Consider a simultaneous second-price, sealed-bid auction for *m* objects. For each object, there are *n* local bidders and *k* global bidders. The local bidders demand only one object. The global bidders demand multiple objects. The local bidder has a private value of *x*, whose value is drawn from the distribution F_L, over the range [0,1]. The global bidder has a private value of *x* for each object, where *x* is drawn from the distribution F_G, over the range [0,1]. If the global bidder wins more than one object, the total value of the package is $bx + \alpha$: where *b* is the number of objects won, *bx* is the sum of the stand-alone values, and α is the positive synergy from winning multiple objects. α does not vary with each global bidder's private valuation of *x*. α is a fixed, positive constant that applies to all global bidders, and whose value is common knowledge. Local and global bidders adopt symmetrical bidding functions within their type.

In the following paragraphs, we review the predicted equilibrium behavior of Krishna and Rosenthal (1996) in relation to our experimental design. Our experimental auction environment comprises two objects, $m = 2$; one local bidder bidding for each object, $n = 1$; two or five global bidders bidding for each object, $k = 2$ *or* 5 and positive synergies of $\alpha = 1$ for global bidders who win both objects.

First, consider the optimal bidding strategy for the local bidders. In a second-price sealed-bid auction, the best response for local bidders is to bid their true valuation:

$$B_L(x) = x, \qquad (1)$$

where $B_L(.)$ represents the local bidder's optimal bidding function, and *x* represents the local bidder's private valuation for the object.

Next, consider the optimal bidding strategy for the global bidders. Global bidders submit two bids, one for each object. Krishna and Rosenthal (1996) restrict their attention to equal-bid pairs. The authors show theoretically that if the bids are not equal, the payoff resulting from one bid will be higher than that from the other bid, even though both objects have the same stand-alone value. Therefore, the best response is to submit equal bids for both objects. We first consider the scenario where the average positive synergy attached to winning each object, $s \approx \frac{\alpha}{2}$, is higher than the stand-alone value of each object, x.

Local bidders draw their valuations from the range [0,1]. When the global bidder's valuation x is such that $x \geq s$, then the global bidder's valuation (including synergies) for one object will be equal to or higher than the maximum possible private valuation of a local bidder for one object. Consequently, local bidders cannot compete against the global bidder. The auction thus becomes equivalent to a standard second-price sealed-bid auction for the package amongst the global bidders. As a result, the global bidders bid their true valuation for each object:

$$B_G(x|x \geq s) = x + s \, , \qquad (2)$$

where $B_G(.)$ represents the global bidder's optimal bidding function, x represents global bidder's private valuation for each object, and s represents the average positive synergy per object.

When $x < s$, the global bidder has to compete against high-private value local bidders as well as global bidders with private values of $x < s$. The differential bid function equation for any k is given in Equation 9 in Krishna and Rosenthal (1996). A closed-form solution for the optimal bidding function for the global bidder is:

$$B_G(x|x \leq s) = \begin{cases} \dfrac{4x}{1+4x^2} & \text{when } k = 2 \\ \dfrac{5x}{2+16x^5} & \text{when } k = 5 \end{cases} \qquad (3)$$

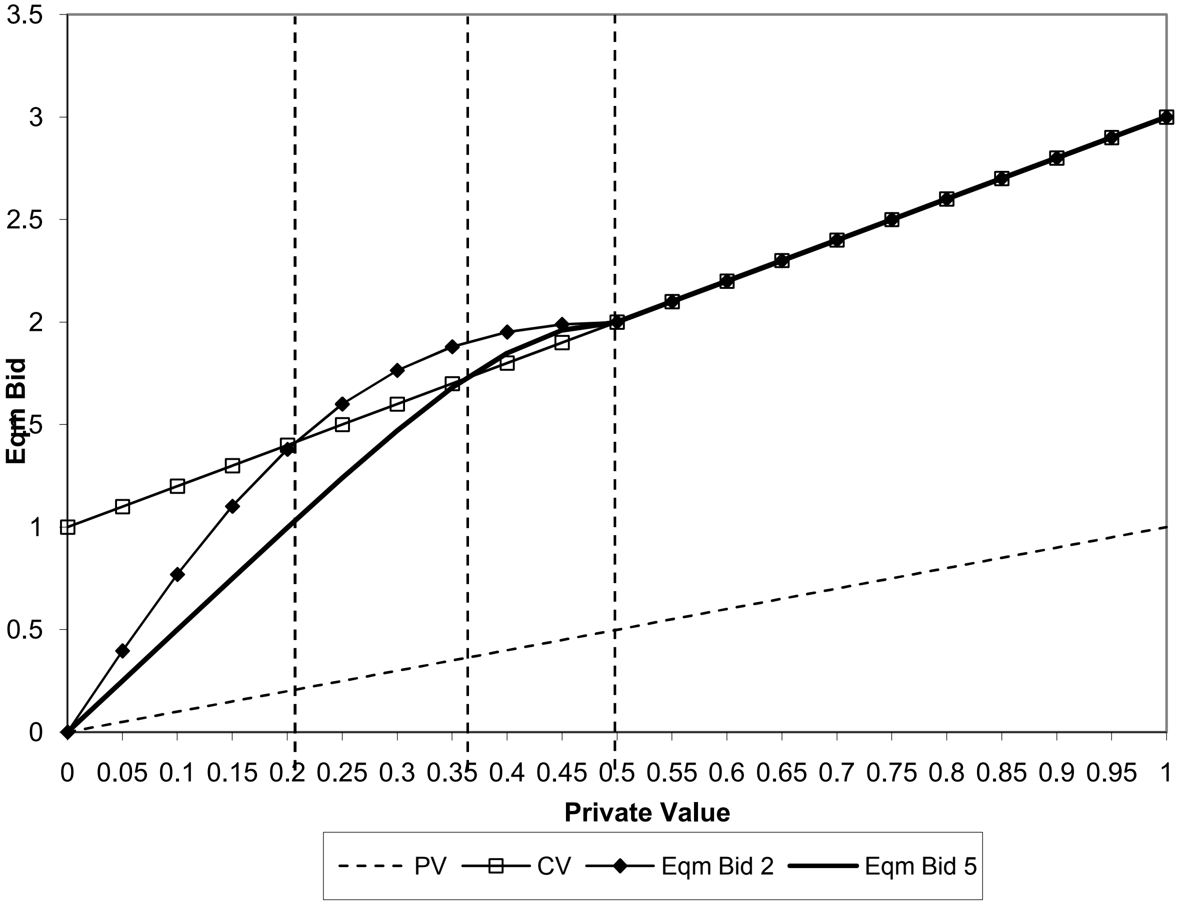
Although the global bidder has drawn a low stand-alone private valuation, synergies provide a positive leverage to the global bidder. The low-private value global bidder leverages on these synergies to bid competitively against the local bidders. These synergies, however, may not be sufficient to allow low-private value global bidders to bid competitively against high-private value global bidders.

If the low-private value global bidder is effectively competing with the local bidders only, this implies that any potential losses due to aggressive overbidding are limited. If local bidders bid optimally, the second-highest losing bid is a maximum bid of 1. In other words, the "price-effect" is minimized. Consequently, the low-private value global bidders may bid aggressively in order to win both objects and capture the positive synergies. This behavior is reflected in Figure 1, which graphs the equilibrium bid functions of the global bidders. When private values are around 0.2 – 0.5 for $k = 2$ and around 0.35 – 0.5 for $k = 5$, the sum of the predicted individual bids are higher than the total value of the package. Kagel and Levin (2005) also predicted a similar "jump" in the bidding function at intermediate private values for uniform-price auctions.

Before proceeding on to describe our experimental design, we provide a brief summary of the theoretical predictions of Krishna and Rosenthal (1996) that can be tested with our experimental design:

(i) Global bidders bid less aggressively when there is increased competition;
(ii) Local bidders bid their private values for the object; and
(iii) Global bidders submit equal bids for the two objects.

Figure 1: Equilibrium Bid Functions for Global Bidders



<u>Key:</u>

PV: Private Value	Eqm Bid 2: Predicted bid when number of global bidders is 2
CV: Combine Value	Eqm Bid 5: Predicted bid when number of global bidders is 5

4 Experimental Design

Following the auction setting in Krishna and Rosenthal (1996), we create a market where a seller sells two objects simultaneously in a second-price sealed-bid auction. There are two types of bidders competing for the objects. A local bidder bids for only one object and a global bidder bids for both objects. The global bidder obtains positive synergies by winning both objects. This positive synergy is a fixed, common value for all global bidders.

In this paper, we investigate whether (i) global bidders bid less aggressively when there are more bidders; and (ii) package bidding leads to higher efficiencies and revenue. Thus, the experiment tests for the effect of increased competition on bidding strategies and for the impact of the package bid option on revenue and efficiency. Table 1 summarizes the experimental design. The experiment comprises four treatments, focusing on two factors:

(i) increasing the number of global bidders , and
(ii) varying the auction format.

Table 1: Design of Treatments

Treatment	Type and Number of Bidders			Number of Subjects	Auction Format	
	Local	Global	Number of Bidders per Group		Simultaneous Bids	Combination Bid
SimOnly2	2	2	4	16	BidOne, BidTwo	
SimOnly5	2	5	7	14	BidOne, BidTwo	
SimCom2	2	2	4	16	BidOne, BidTwo	BidCom
SimCom5	2	5	7	14	BidOne, BidTwo	BidCom

Key:
SimOnly2: Simultaneous-only auction with two global bidders.
SimOnly5: Simultaneous-only auction with five global bidders.
SimCom2: Simultaneous-Combination auction with two global bidders.
SimCom5: Simultaneous-Combination auction with five global bidders.
BidOne: Bid submitted for Object One.
Bid Two: Bid submitted for Object Two.
BidCom: Bid submitted for the package.

For the first factor, we test bidders' behavior by increasing the number of global bidders from two to five. Referring to Table 1, SimOnly2 and SimCom2 represent treatments where there are two global bidders. SimOnly5 and SimCom5 represent treatments where there are five global bidders. In the experimental literature for testing the effect of an increase in the number of bidders, two experimental designs – cross-over and change-over – are often applied (Battalio et al, 1990; Kagel and Levin, 1993). These two designs primarily limit the impact of subject heterogeneity on bidding. In our study, taking into consideration the fact that subjects have to bid in a multiple-object environment and that they have to change roles (global or local bidder) randomly during the game, inserting the two designs may further confuse the subjects. Consequently, subjects may not be able to focus on how they should bid in the specified auction environment. Therefore, we did not apply the two designs but rely instead on statistical methods to adjust for subject heterogeneity.

For the second factor, we test for changes in revenue and efficiency in a simultaneous-only auction against a simultaneous-combination auction. Again, referring to Table 1, SimOnly2 and SimOnly5 are simultaneous-only auction markets where global bidders simultaneously submit two bids, BidOne for Object One and BidTwo for Object Two. SimCom2 and SimCom5 are simultaneous-combination auction markets where global bidders simultaneously submit three bids, BidOne, BidTwo, and BidCom for the two objects together as a package.

In the SimOnly treatments, each object is awarded following standard second-price sealed bid auction rules: the highest bidder wins the object and pays the highest losing bid. In the SimCom treatments, there is an additional combination option for the global bidders. The seller can award the objects separately or award both objects as one package. To determine the award, we compare the value from the highest of the package bids (BidCom) with the summed value of the highest of the individual bids for object one (BidOne) and the highest of the individual bids for object two (BidTwo). If the summed value is higher, the objects are awarded separately. Each winner pays the respective highest losing bid for each object. If the value from the package bid is higher, both objects are awarded as a package to one bidder. The bidder who submits the highest bid for BidCom wins the package and pays the highest losing bid for the package.

There are twenty-three periods in the auction market; the first three periods are practice periods. In each period, for each group, there are two objects for sale. Subjects are randomly arranged into groups. Subjects are also randomly assigned to be either a local bidder[iii] or a global bidder in each period; hence, their role can change from one period to another[iv]. Each subject is assigned a private value for a unit of the object at the beginning of each period and these private values are randomly drawn from a uniform distribution on the interval [0,100]. In the experiment, bidders are told their valuations in points, and bidders bid in points. For the global bidders, the same private value applies to both objects. In addition, global bidders obtain a positive synergy of 100 points when they win both objects. This 100 point bonus is common to all global bidders.

Bidders know their private valuations for the objects, the distribution from which other bidders' private valuations for the objects are drawn, and the number of bidders. At the end of each period, bidders are told what they won, if any, and the price they have to pay for the object/s. A bidder's profit is the difference between his/her value of the object and the price paid for the object.

In all treatments, there are two local bidders: one for each object. In the SimOnly2 and SimCom2 treatments, there are two local bidders and two global bidders in each bidding group. In the SimOnly5 and SimCom5 treatments, there are two local bidders and five global bidders in each bidding group. At the beginning of the experiment, all bidders are

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[iii] In Kagel and Levin (2001, 2005), computers play the role of single-unit bidders and are programmed to bid their private value for the object. In our design, subjects play the role of single-unit bidders and our results show that in some cases, local bidders do not play their dominant strategy of bidding their private values.

[iv] In our game, winners of the auction predominantly tend to be global bidders. If a particular subject ends up being a local bidder too often, this may cause overly aggressive or irrational bidding behavior to arise during the experiment. Hence, in each treatment, we ensure that all subjects have equal opportunities of being assigned a global bidder.

given points that are equivalent in value to US$10[v]. At the end of the experiment, these points are converted to cash at a pre-specified exchange rate[vi] that was announced in the instructions.

Subjects were recruited from undergraduates and graduate students enrolled at the Pennsylvania State University. No subject was allowed to participate in more than one session. At the start of each session, instructions were read out-loud and at the end of the reading, the subjects took a short 5-minute multiple-choice quiz to make sure they understood the auction rules. After going through the answers, the instructor started the experiment. A total of twelve experimental sessions were conducted over three periods: April 2007, September 2007 and February 2008. Three sessions were held for each treatment. All sessions were held at the LEMA (Laboratory for Economic Management and Auctions) at the Pennsylvania State University and the experiment was programmed with the z-Tree software developed by Fischbacher (2007).

5 Experimental Results

Twelve experimental sessions were conducted and observations from the last ten periods of each session are used in the analysis[vii]. In total, our data consists of 3,713 bids.

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[v] In Krishna and Rosenthal (1996), bidders are predicted to bid above their private values. Given this possibility, subjects were given starting balances of US$10 in all treatments. The show-up fee of $5 was included in the starting balance. On average, each subject earned $27(SimOnly treatments) and $25(SimCom treatments). Each session lasted about 75 minutes. There were two bankruptcies, one in SimOnly5 and one in SimCom5. They were made to pay back the monies owed through clerical work at the rate of $10 per hour.

[vi] The exchange rate for treatments with two global bidders is 0.045 and bidders have a starting balance of 220 points. The exchange rate for treatments with five global bidders is 0.15 and bidders have a starting balance of 70 points. The exchange rates were set to equalize the expected earnings across the two treatments.

[vii] We removed bids submitted by subjects who went bankrupt during the game. One subject went bankrupt in the first SimOnly5 session. This subject, despite answering the questionnaire correctly, misunderstood how the positive synergy component was awarded. The other subject went bankrupt in the first SimCom5 session. This subject was bidding too aggressively in the first few periods of the game. Their data was removed from the analysis. The same instructor read the same instructions in the same manner in all sessions. All subjects were recruited in the same manner. We still use data from the two sessions in which these two subjects participated, because during the session, subjects were not given any other information than their private value of the object.

We test for the effect of increased competition on bidding behavior using the bid difference (BidDiff):

$$BidDiff_{it} = \frac{Bid_{it} - PV_{it}}{PV_{it}},$$

$$BidDiffCom_{it} = \frac{BidCom_{it} - CV_{it}}{CV_{it}},$$

where

$BidDiff_{it}$: Percentage bid difference for the individual object by subject *i* in period *t*.
$BidDiffCom_{it}$: Percentage bid difference for the package by subject *i* in period *t*.
PV_{it} : Private value for the individual object of subject *i* in period *t*.
CV_{it} : Value of the package, including the positive synergies of subject *i* in period *t*.

We refer to Table 2 for a summary of the average differences classified by auction format and private value. High-private value bidders have in general much lower bid differences than low-private value bidders. First, we look at the bidding behavior of the global bidders. In the SimOnly treatment, high-private value global bidders bid 48% above the stand-alone value while low-private value global bidders bid about 214% above the stand-alone value. In the SimCom treatment, for the individual bids, high-private value global bidders bid 5% above the stand-alone value while low-private value global bidders bid 87% above stand-alone value. For the package bid, high-private value bidders bid 5% above the value for the package while low-private value bidders bid their private values.

Next, we look at the bidding behavior of the local bidders. In the SimOnly treatment, high- and low-private value local bidders tend to bid around their private values. In the SimCom treatment, high-private value bidders have lower bid differences (7%-12%) than low-private value bidders (15%-30%).

From these findings, we observe that when global bidders are not allowed to submit bids for the package, they bid above stand-alone values. When global bidders are allowed to submit bids for the package, they lower their bids for the individual objects closer to their private values.

Table 2: Average Bid Differences by Treatments and Private Values

Bidder	SimOnly		SimCom		
	BidOne	BidTwo	BidOne	BidTwo	BidCom
HPV_G	0.48	0.48	0.05	0.05	0.05
LPV_G	2.09	2.19	0.88	0.86	0.00
HPV_L	0.00	0.00	0.12	0.07	-
LPV_L	0.03	-0.02	0.30	0.15	-

Key

HPV_G	: High-private value (51-100 points) global bidders.
LPV_G	: Low-private value (0-50 points) global bidders.
HPV_L	: High-private value local bidders.
LPV_L	: Low-private value local bidders.

5.1 Bidding Behavior

First, we address our central research question: Do bidders bid more or *less* aggressively with increased competition? We compare the bidding pattern between groups with two global bidders and groups with five global bidders. We conduct a two-tail test for the null hypothesis that the two groups have the same bid differences, against the alternative hypothesis that the two groups have different bid differences. The hypotheses are tested using the non-parametric Wilcoxon signed-rank tests and rank-sum tests.

Conclusion 1: Global bidders bid less aggressively with more rival bidders.

We refer to the predicted equilibrium bidding function of Krishna and Rosenthal (1996) displayed in Figure 1. We principally test for two points in the SimOnly treatments: (i) Low-private value global bidders bid less aggressively with increased competition; and (ii) High-private value global bidders have the same bidding strategy, regardless of the number of competing global bidders. Our results support these two points.

In the SimOnly treatments, low-private value global bidders are bidding less aggressively with increased competition. Referring to Table 3, Panel A1, column (5), z-statistics are positive and highly significant for BidDiffOne (z = 2.006, p-value = 0.0448) and BidDiffTwo (z = 2.335, p-value = 0.0195). High-private value global bidders, however, apply similar bid differences in their bidding, even with more bidders. Referring to column (3), although the bid differences are negative between the two groups, this difference is not statistically significant. Therefore, for high-value global bidders we do not reject the null hypothesis that the bid differences are the same between the two groups.

Surprisingly, we find that conclusion 1 extends to the package bids submitted by the global bidders in the SimCom treatment. We wish to point out that Krishna and Rosenthal (1996) do not model the SimCom auction format. Hence, their prediction that global bidders bid less aggressively with more rival bidders does not extend to the SimCom treatment. In the package bid (BidCom), competition for the package is among the global bidders only. Thus, one can view the package bidding as a second-price sealed-bid auction for one "object". Bidders' best response is to bid their combined value for the package; thus, the number of bidders should not affect the bidding strategy.

Our results indicate, however, that when global bidders place bids for individual objects as well as for the package and when they face competition from local bidders for individual objects, their bidding behavior changes with the number of global bidders. Referring to columns (4) and (6), the bid differences for the package bid are positive and highly significant for the global bidders.

Table 3: Hypotheses Testing

	By Auction Format		High-Private Value		Low-Private Value	
Null Hypotheses	**SimOnly (1)**	**SimCom (2)**	**SimOnlyHPV (3)**	**SimComHPV (4)**	**SimOnlyLPV (5)**	**SimComLPV (6)**
Panel A1: Global Bidders						
H_0: $BidDiffOne_2 = BidDiffOne_5$	1.505 (0.1325)	-0.084 (0.9331)	-0.46 (0.6452)	0.455 (0.6494)	2.006 (0.0448)**	-0.519 (0.6040)
H_0: $BidDiffTwo_2 = BidDiffTwo_5$	1.557 (0.1194)	0.809 (0.4183)	-0.75 (0.4534)	1.172 (0.2411)	2.335 (0.0195)**	0.055 (0.9561)
H_0: $BidDiffCom_2 = BidDiffCom_5$		4.327 (0.0000)		3.508 (0.0005)**		2.689 (0.0072)**
Panel A2: Local Bidders						
H_0: $BidDiffOne_2 = BidDiffOne_5$	2.894 (0.0038)**	2.971 (0.0030)**	3.203 (0.0014)**	2.247 (0.0246)**	1.378 (0.1683)	1.979 (0.0478)**
H_0: $BidDiffTwo_2 = BidDiffTwo_5$	3.047 (0.0023)**	1.813 (0.0698)*	3.193 (0.0014)**	1.753 (0.0796)*	1.494 (0.1352)	0.719 (0.4721)

Note:
** denotes significance at the 5% level.
* denotes significance at the 10% level.
The numbers shown here are the z-statistics, the p-values are shown in the brackets.

Key:
$BidOne_2$: Bid submitted for Item One in the auction market with 2 global bidders.
$BidDiffOne_2$: Percentage bid difference from the bidder's private value for the item in bid submitted for Item One in the auction market with 2 global bidders.
$BidTwo_2$:Bid submitted for Item Two in the auction market with 2 global bidders.
$BidDiffTwo_2$: Percentage bid difference from the bidder's private value for the item in bid submitted for Item Two in the auction market with 2 global bidders.
$BidOne_5$: Bid submitted for Item One in the auction market with 5 global bidders.
$BidDiffOne_5$: Percentage bid difference from the bidder's private value for the item in bid submitted for Item One in the auction market with 5 global bidders.
$BidTwo_5$:Bid submitted for Item Two in the auction market with 5 global bidders.
$BidDiffTwo_5$: Percentage bid difference from the bidder's private value for the item in bid submitted for Item Two in the auction market with 5 global bidders.
$BidCom_2$: Bid submitted for the package in the auction market with 2 global bidders.
$BidDiffCom_2$: Percentage bid difference from the bidder's combined value for the package in bid submitted for the package in the auction market with 2 global bidders.
$BidCom_5$: Bid submitted for the package in the auction market with 5 global bidders.
$BidDiffCom_5$: Percentage bid difference from the bidder's combined value for the package in bid submitted for the package in the auction market with 5 global bidders.
HPV : Refers to bidders whose private value for the individual item is between 51-100 points.
LPV : Refers to bidders whose private value for the individual item is between 0-50 points.

When we look at the bid differences for the individual objects (BidDiffOne and BidDiffTwo) by global bidders in the SimCom treatment, we find that we cannot reject the null hypothesis that the bid differences in the bids submitted by global bidders in a market with two global bidders are similar to those submitted by global bidders in a market with five global bidders (Table 3, Panel A1, columns (4) and (6)).

For the local bidders, we find that high-private value local bidders bid less aggressively with more bidders, whereas low-private value local bidders have similar bid differences. Referring to Panel A2, columns (3) and (4), the z-statistics for the bid differences for high-private value local bidders are positive and are statistically significant. The z-statistics for the bid differences for low-private value local bidders, columns (5) and (6), are predominantly statistically insignificant.

Besides using the Wilcoxon ranksum test to provide support for conclusion 1, we also conduct a random effects regression to obtain a more statistically rigorous test on the data. From our descriptive analysis, we find that the bid differences for bidding on individual objects display a decreasing slope: bid differences become smaller as private values increase. Taking this into account, we fit the following random effects model to our data:

$$BidDiff_{it}(x) = \beta_0 + \beta_1 \frac{1}{x_{it}} + \beta_2 D5 \frac{1}{x_{it}} + [s_i + e_{it}],$$

$$BidDiffCom_{it}(x) = \beta_0 + \beta_1 x_{it} + \beta_2 D5 x_{it} + [s_i + e_{it}],$$

where

$BidDiff_{it}$: Bid difference for individual object by subject *i* at time *t*.

$BidDiffCom_{it}$: Bid difference for package by subject *i* at time *t*.

$\frac{1}{x_{it}}$: inverse of the private value of subject *i* at time *t*.

x_{it} : Private value of subject *i* at time *t*.

$D5$: dummy variable that is equal to 1 when there are five global bidders.

s_i : dummy variable for each subject.

e_{it} : error term.

In these regressions, we are principally interested in the sign and significant of β_2. We expect the sign for β_2 to be negative. When there are five global bidders, bid differences should decrease. We report the estimation results for the SimOnly treatments in Table 4 and the SimCom treatments in Table 5 . Results from the estimated regressions provide further support for conclusion 1. In the SimOnly treatments, β_2 is negative and highly significant for both the global and local bidders. In the SimCom treatment, β_2 is negative but is significant only for the global bidders, both for the individual object bids and for the package bid.

The bottom panels of Table 4 and Table 5 present test statistics that check for the correct fitting of the regressions. We apply the Hausman test to examine whether a fixed effect or a random effect model is more suitable for our data. The Hausman test statistic for all the models rejects the null hypothesis that the individual effects are uncorrelated with the other regressors in the model. The random effects model is suitable for our data analysis.

We apply the Breusch-Pagan Lagrange multiplier (LM) test to study whether a random effects or a classical regression is more appropriate for our data. The LM test rejects the null hypothesis that variances of the groups are zero. Hence, the classical regression model is inappropriate for our data. We also apply the Breusch-Pagan LM test to check whether we have to account for period effects in the data. In general, the chi-square values do not reject the null hypothesis that the variance components for periods are zero. Hence, we assume that the period effect does not have a significant impact on the bids submitted.

Table 4: Random Effects Panel Regression for SimOnly Treatments

SimOnly	**Global BidDiffOne**	**Global BidDiffTwo**	**Local BidDiffOne**	**Local BidDiffTwo**
constant	0.0640 (0.631)	0.1396 (0.297)	0.0009 (0.983)	0.0292 (0.268)
invpv ($1/x_{it}$)	28.4070** (0.000)	30.7269** (0.000)	1.9210** (0.008)	0.0004 (0.989)
d5invpv ($D5(1/x_t)$)	-3.9783** (0.024)	-4.0474** (0.019)	-2.7068** (0.009)	-2.3268** (0.040)
Rsq	0.5678	0.6186	0.0493	0.0262
Wald chi2	783.4200 (0.000)	968.98 (0.000)	9.43 (0.0089)	4.43 (0.1094)
Hausman Test	0.89 (0.639)	0.07 (0.966)	0.39 (0.824)	0.90 (0.638)
BP LM Test (RE)	12.02** (0.000)	16.21** (0.000)	17.75** (0.000)	33.68** (0.000)
BP LM Test (TE)	1.50 (0.221)	1.62 (0.203)	2.11 (0.147)	0.00 (0.977)

Note
** indicates significance at the 5% level
* indicates significance at the 10% level
The p-values are shown in paranthesis.
BP LM Test (RE) : Breusch-Pagan Lagrange Multiplier test for random effects
BP LM Test (TE) : Breusch-Pagan Lagrange Multiplier test for time effects

Table 5: Random Effects Panel Regression for SimCom Treatments

SimCom	Global BidDiffOne	Global BidDiffTwo	Local BidDiffOne	Local BidDiffTwo^{+}
constant	-0.0631 (0.633)	-0.0787 (0.550)	0.1667** (0.041)	-0.1206 (0.298)
invpv ($1/x_{it}$)	12.5856** (0.000)	12.9817** (0.000)	2.9140** (0.027)	1.0569 (0.372)
d5invpv ($D5(1/x_{it})$)	-4.6355** (0.006)	-5.1330** (0.002)	-2.522 (0.192)	-1.5770 (0.488)
Rsq	0.1793	0.1866	0.0246	0.0951
Wald chi2	134.18 (0.000)	140.62 (0.000)	4.95 (0.084)	23.58 (0.023)
Hausman Test	0.90 (0.638)	2.14 (0.343)	0.87 (0.649)	0.22 (0.895)
BP LM Test (RE)	7.81** (0.005)	7.26** (0.007)	58.18** (0.000)	191.06** (0.000)
BP LM Test (TE)	1.66 (0.197)	1.21 (0.272)	1.02 (0.312)	3.03* (0.082)

SimCom	Global BidDiffCom
constant	-0.0038 (0.884)
pv (x_{it})	-0.0001 (0.756)
d5pv ($D5x_{it}$)	-0.0007* (0.072)
Rsq	0.0153
Wald chi2	7.96 (0.019)
Hausman Test	0.07 (0.9643)
BP LM Test (RE)	680.53** (0.000)
BP LM Test (TE)	0.05 (0.819)

Note
** indicates significance at the 5% level
* indicates significance at the 10% level
+ time effects are included in the random effects estimation
The p-values are shown in paranthesis
BP LM Test (RE) : Breusch-Pagan Lagrange Multiplier test for random effects
BP LM Test (TE) : Breusch-Pagan Lagrange Multiplier test for time effects

Next, we compare the bidding behavior of bidders with respect to their private value of the objects. We conduct a two-tail test for the null hypotheses that when bidding for the individual objects, bidders bid their private value of the object; and when bidding for the package, bidders bid their combined value for the package. The alternative hypotheses are that bidders bid differently from their private value for the individual objects and combined value for the package. We conclude that:

Conclusion 2: Global bidders generally bid above their stand-alone valuations but below their predicted bids (given by equations 2 and 3) when bidding for the objects individually. Global bidders bid above the value for the package with fewer rival bidders.

First, we look at the case in which global bidders bid for the individual objects. We refer to Table 6, Panel B1. For the SimOnly treatments (columns (1) and (3)), bidders bid above their private value for the individual objects. This is aligned with our earlier discussion in Section 2.1 that bidders bid above the stand-alone valuation for the individual object. Our hypothesis testing confirms that this finding is statistically significant. The z-statistics are positive and highly significant. Global bidders bid below the predicted values given by Equations (2) and (3). The z-statistics are negative and statistically significant.

For the SimCom treatments, low-private value global bidders (column (4)) bid above their stand-alone values for the individual objects and bid above the combined value for the package when there are two global bidders. High-private value global bidders (column (2)) bid above their stand-alone values for the individual objects and bid above the combined value for the package when there are two global bidders. When there are five global bidders, at the 5% significance level, we do not reject the null hypothesis that global bidders bid at their private values for the individual objects, and they bid below their combined value for the package.

For the local bidders, we conclude that:

Conclusion 3: Local bidders bid above their private values when there are two global bidders, but bid their private values when there are five global bidders.

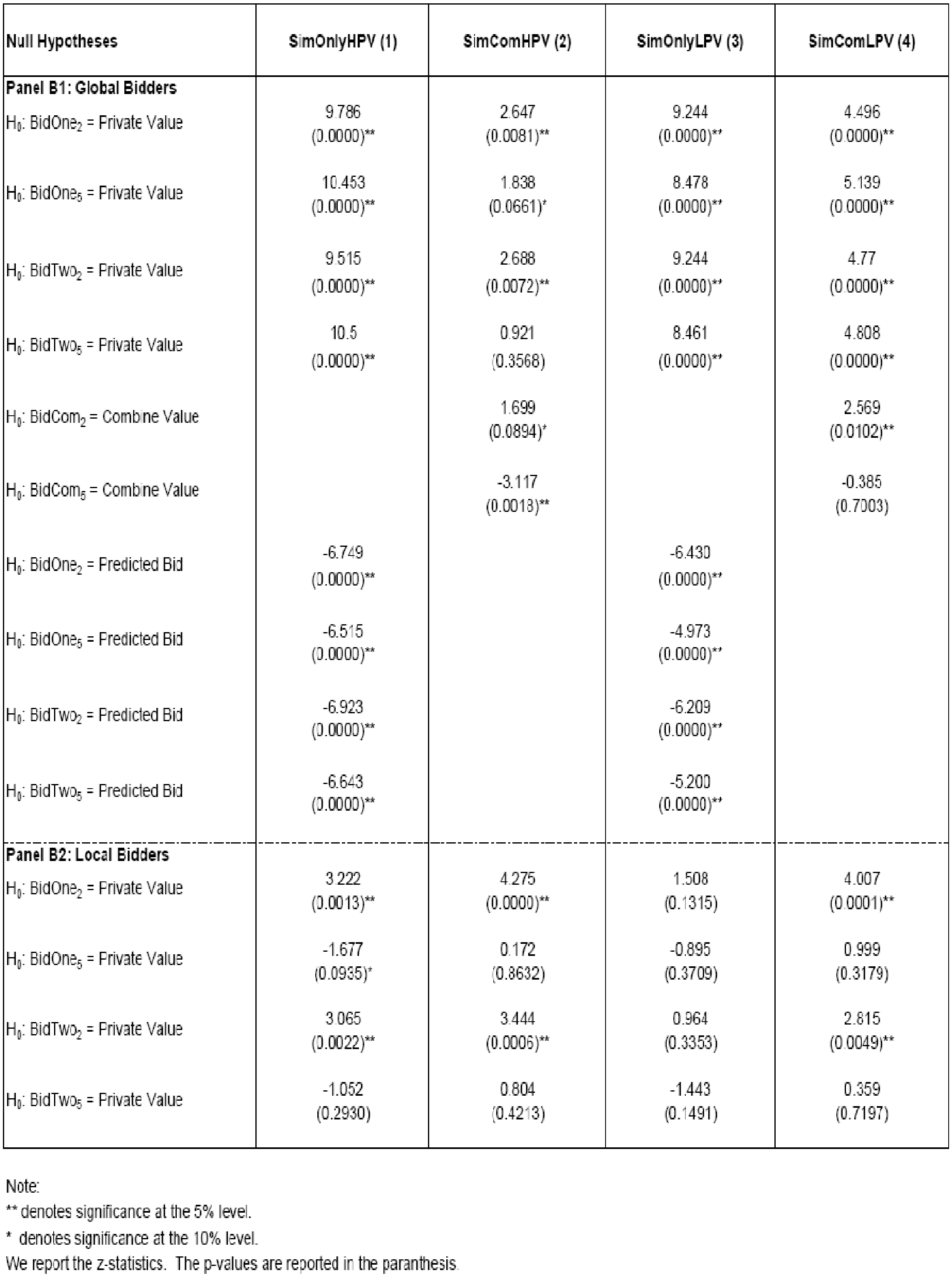
We refer to Table 6, Panel B2. In general, local bidders in auction markets with two global bidders bid above their private values. The z-statistics, shown in columns (1), (2), and (4), are positive and statistically significant. The exception is the low-private value local bidders who bid at their private values.

For local bidders in auction markets with five global bidders, local bidders bid at their private values. The z-statistics are statistically insignificant at the 5% level; thus we do not reject the null hypothesis.

Hereafter, we focus on the bidding patterns of the global bidders. We test for three types of bidding behavior, whether:

(i) Bidders submit equal bids for the two objects;
(ii) Bidders follow a naïve strategy of splitting the positive synergies in their bids;
(iii) Bidders in the SimCom treatments are bidding in favor of the combination bid.

Table 6: Hypotheses Testing



Null Hypotheses	SimOnlyHPV (1)	SimComHPV (2)	SimOnlyLPV (3)	SimComLPV (4)
Panel B1: Global Bidders				
H_0: BidOne$_2$ = Private Value	9.786 (0.0000)**	2.647 (0.0081)**	9.244 (0.0000)**	4.496 (0.0000)**
H_0: BidOne$_5$ = Private Value	10.453 (0.0000)**	1.838 (0.0661)*	8.478 (0.0000)**	5.139 (0.0000)**
H_0: BidTwo$_2$ = Private Value	9.515 (0.0000)**	2.688 (0.0072)**	9.244 (0.0000)**	4.77 (0.0000)**
H_0: BidTwo$_5$ = Private Value	10.5 (0.0000)**	0.921 (0.3568)	8.461 (0.0000)**	4.808 (0.0000)**
H_0: BidCom$_2$ = Combine Value		1.699 (0.0894)*		2.569 (0.0102)**
H_0: BidCom$_5$ = Combine Value		-3.117 (0.0018)**		-0.385 (0.7003)
H_0: BidOne$_2$ = Predicted Bid	-6.749 (0.0000)**		-6.430 (0.0000)**	
H_0: BidOne$_5$ = Predicted Bid	-6.515 (0.0000)**		-4.973 (0.0000)**	
H_0: BidTwo$_2$ = Predicted Bid	-6.923 (0.0000)**		-6.209 (0.0000)**	
H_0: BidTwo$_5$ = Predicted Bid	-6.643 (0.0000)**		-5.200 (0.0000)**	
Panel B2: Local Bidders				
H_0: BidOne$_2$ = Private Value	3.222 (0.0013)**	4.275 (0.0000)**	1.508 (0.1315)	4.007 (0.0001)**
H_0: BidOne$_5$ = Private Value	-1.677 (0.0935)*	0.172 (0.8632)	-0.895 (0.3709)	0.999 (0.3179)
H_0: BidTwo$_2$ = Private Value	3.065 (0.0022)**	3.444 (0.0006)**	0.964 (0.3353)	2.815 (0.0049)**
H_0: BidTwo$_5$ = Private Value	-1.052 (0.2930)	0.804 (0.4213)	-1.443 (0.1491)	0.359 (0.7197)

Note:

** denotes significance at the 5% level.

* denotes significance at the 10% level.

We report the z-statistics. The p-values are reported in the paranthesis.

We look at the first type of bidding behavior. We conduct a two-tail test for the null hypothesis that bidders submit equal bids for each individual object, against the alternative hypothesis that the bids are not equal. We conclude the following:

Conclusion 4: Global bidders submit equal bids for the individual objects.

We refer to Table 7, Panel C1. In general, all the z-statistics are statistically insignificant at the 5% level. Hence, we do not reject the null hypothesis that bidders submit equal bids for the individual objects. There is an exception to this finding. High-private value global bidders in the auction market with 2 global bidder, participating in the SimCom treatment (column (2)) submit a lower bid for Object One than for Object Two (z = -2.434, p-value = 0.0149).

As a possible explanation of the bidding behavior observed in the experiment, we want to test whether bidders naively split the synergies in bidding for each individual object. In other words, we want to test whether bidders adopt the strategy of bidding at private value plus fifty points for the individual object, for private values [0,100]. Note that this is the predicted optimal bidding function for high-private value global bidders in the SimOnly treatments, but not for the low-private value bidders.

Conclusion 5: Global Bidders do not follow the naïve strategy of splitting the positive synergies for the individual objects.

We refer to Table 7, Panel C2. Global bidders do not follow the naïve bidding strategy. The z-statistics are negative and statistically significant. We note that high-private value global bidders in the SimOnly treatments are bidding below the predicted bids.

Table 7: Hypotheses Testing

Null Hypotheses	SimOnlyHPV (1)	SimComHPV (2)	SimOnlyLPV (3)	SimComLPV (4)
Panel C1: Global Bidders				
H_0: $BidOne_2 = BidTwo_2$	-0.376 (0.7067)	-2.434 (0.0149)**	-1.688 (0.0913)*	-0.585 (0.5584)
H_0: $BidDiffOne_2 = BidDiffTwo_2$	-0.384 (0.7009)	-2.426 (0.0153)**	-1.71 (0.0872)*	-0.585 (0.5584)
H_0: $BidOne_5 = BidTwo_5$	0.012 (0.9903)	0.428 (0.6684)	1.684 (0.0923)*	0.461 (0.6451)
H_0: $BidDiffOne_5 = BidDiffTwo_5$	0.029 (0.9765)	0.413 (0.6792)	1.666 (0.0956)*	0.431 (0.6667)
Panel C2: Global Bidders				
H_0: $BidOne_2$ = Private Value + 50	-6.749 (0.0000)**	-9.403 (0.0000)**	-7.52 (0.0000)**	-8.894 (0.0000)**
H_0: $BidOne_5$ = Private Value + 50	-6.515 (0.0000)**	-10.531 (0.0000)**	-8.814 (0.0000)**	-10.561 (0.0000)**
H_0: $BidTwo_2$ = Private Value + 50	-6.923 (0.0000)**	-9.215 (0.0000)**	-7.504 (0.0000)**	-9.094 (0.0000)**
H_0: $BidTwo_5$ = Private Value + 50	-6.643 (0.0000)**	-10.472 (0.0000)**	-9.113 (0.0000)**	-10.382 (0.0000)**
Panel C3: Global Bidders				
H_0: $SumBid_2$ = Combine Value	-6.941 (0.0000)**	-9.378 (0.0000)**	-7.516 (0.0000)**	-9.137 (0.0000)**
H_0: $SumBid_5$ = Combine Value	-6.618 (0.0000)**	-10.54 (0.0000)**	-9.013 (0.0000)**	-10.83 (0.0000)**
Panel C4: Global Bidders				
H_0: $SumBid_2 = BidCom_2$		-8.758 (0.0000)**		-9.156 (0.0000)**
H_0: $SumBid_5 = BidCom_5$		-8.82 (0.0000)**		-10.184 (0.0000)**

Note:
** denotes significance at the 5% level.
* denotes significance at the 10% level.
We report the z-statistics. The p-values are reported in the paranthesis.

Key
$SumBid_2$: The sum of BidOne and BidTwo, of the i^{th} bidder in the auction market with 2 global bidders. $SumBid_2 = BidOne_2 + BidTwo_2$
$SumBid_5$: The sum of BidOne and BidTwo, of the i^{th} bidder in the auction market with 5 global bidders. $SumBid_5 = BidOne_5 + BidTwo_5$
Combine Value : Refers to the total value of the package, including the positive synergies.

For the third type of bidding behavior, we want to test whether global bidders' bids in the SimCom treatments exhibit a more aggressive bidding, vis-à-vis their private values, for the package than for the individual objects. To recap, in the SimCom treatments, a global bidder submits three bids: One bid for Object 1, one bid for Object 2 and one bid for the two objects as a package. Consequently, when bidding simultaneously for the objects both individually and as a package, all bids are competitor bids. To minimize the "exposure" problem, a bidder is likely to strategize the bids in favor of the package (Colwell and Yavas, 1994; Krishna and Rosenthal, 1996; Cantillon and Pesendorfer, 2006). Bidders in the SimCom treatment may be strategically placing their bets on the package option to win the objects as a package rather than winning each object individually. In addition, the package bid eliminates the "exposure" problem by providing them with the certainty of winning both objects together and enjoying the positive synergies.

Conclusion 6: When bidders have the option to bid for the objects both individually and as a package, bidders structure their bids in favor of the packaged bid.

In the SimCom treatments, we note from results shown earlier in Table 6 that the global bidders bid above the stand-alone value for the individual objects. However, our results in Table 7, Panel C3, columns (2) and (4), show that the summed value of the bids for the individual objects (hereafter referred to as summed value) is less than the combined value of the package. This means that although global bidders are bidding above the stand-alone value for the individual objects, the summed value is still below the combined value for the package. More importantly, our results show that the summed value is below the bid for the package (Table 7, Panel C4).

5.2 Efficiency, Revenue, Bidders' Surplus

In this section we principally compare three standard performance measures of auction mechanisms: allocative efficiency, sellers' revenue and bidders' surplus. We compare these performance measures on two levels. The first is between the two auction formats and the second is the number of competitor bidders within the same auction format.

Following the commonly used definitions of these measures in the literature, we define the three measures as:

$$Eff_{gt} = \frac{WinVal_{gt}}{MaxVal_{gt}},$$

$$Rv_{gt} = \frac{Paym_{gt}}{MaxVal_{gt}},$$

$$BS_{gt} = \frac{WinVal_{gt} - Paym_{gt}}{MaxVal_{gt}},$$

where

Eff_{gt} : Allocative efficiency of bidding group *g*, in period *t*.

Rv_{gt} : Revenue obtained by the seller from bidding group *g*, in period *t*.

BS_{gt} : Bidders' surplus of bidding group *g*, in period *t*.

$WinVal_{gt}$: Winning valuation of bidding group *g*, in period *t*. If both objects are won by the same winner, WinVal = combined value of the winner. If the two objects are won by two separate winners, WinVal = summed private values of the winners.

$MaxVal_{gt}$: Maximum valuation of the two objects of bidding group *g*, in period *t*.

$Paym_{gt}$: Price paid to the seller by the winner/s of bidding group *g*, in period *t*.

From our results, we arrive at the following conclusions:

Conclusion 7: Efficiency and revenue are higher when package bidding is allowed.

Conclusion 8: Revenue increases with more bidders[viii]*. Revenue also increases when package bidding is allowed.*

Conclusion 9: Bidders' surplus decreases with more bidders.

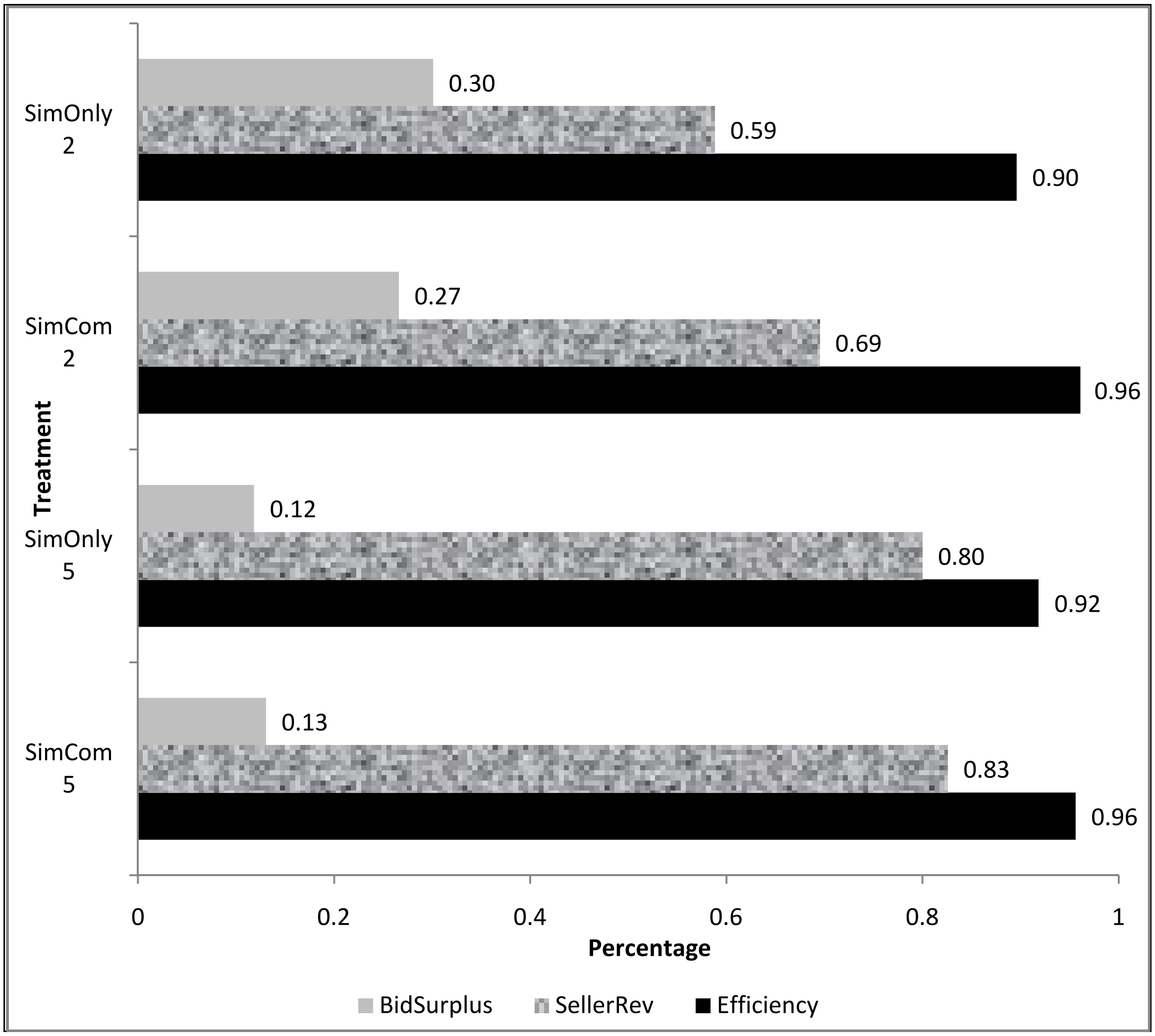
[viii] At first this finding may seem contradictory to our earlier result that global bidders bid *less* aggressively with more rival bidders. Our experiment utilizes a second-price sealed-bid auction whereby the winner pays the second-highest losing bid. Consequently, even though global bidders bid less aggressively with increased competition, the price paid by the winning bidder, i.e., the expected value of the second highest bid, could still be higher when there are more global bidders. Hence, this finding is not contradicting our earlier result.

We start by comparing the overall performance of the four treatments. Figure 2 presents the average performance measures. Allocative efficiency and sellers' revenue are higher in the SimCom treatments than in the SimOnly treatments. Allocative efficiency and sellers' revenue increase when there are more rival bidders. Controlling for the number of bidders, allocative efficiency and sellers' revenue increase when global bidders are offered the additional option to bid for both objects as a package. The reverse is true for the bidders' surplus. Bidders' surplus is lower in the SimCom treatments than in the SimOnly treatments. Bidders' surplus decreases when there are more rival bidders.

Next, we statistically compare the performance measures between different treatments. Table 8 summarizes the descriptive statistics. Firstly, we look at the allocative efficiency measure. Within the same auction format, allocative efficiency is similar between auction markets with two global bidders and five global bidders. Comparing between auction formats, allocative efficiency is higher in the SimCom treatments than in the SimOnly treatments. In the SimOnly treatment, allocative efficiency increases when there are five global bidders (column (1): z=0.738, p-value=0.4606) whereas in the SimCom treatment, allocative efficiency decreases when there are five global bidders (column (2): z=1.900, p-value=0.0574). However, these differences are not statistically significant at the 5% level. Thus, we do not reject the null hypothesis that allocative efficiency within the same auction format is similar whether there are two or five global bidders. Controlling for the number of bidders, we observe that allocative efficiency is 4%-7% [ix] higher in the SimCom treatments than in the SimOnly treatments. When there are two global bidders, this difference is highly statistically significant (column (3): z=-3.573, p-value=0.0004). When there are five global bidders, this difference is significant at the 10% level (column (4): z=-1.868, p-value=0.0617).

[ix] We took the difference in the average statistics. When there are two global bidders, the difference is 7% (0.8957-0.9607=-0.065).

Figure 2: Performance Measures of the Four Treatments



Secondly, we look at sellers' revenue measure. Within the same auction format, revenue is higher when there are more rival bidders, and the magnitude of this difference is lower when global bidders are offered an additional option to submit bids for both objects as a package. These observations are highly statistically significant. In the SimOnly treatment, revenue increases by 21% when there are more rival bidders (column (1): z=-7.362, p-value=0.0000). In the SimCom treatment, revenue increases by 13% when there are more rival bidders (column (2): z=-4.336, p-value=0.0000). Controlling for the number of bidders, we observe that when there are two global bidders, revenue is 11% higher in the SimCom treatment than in the SimOnly treatment. This difference is highly statistically significant (column (3): t=-4.3057[x], p-value=0.0000). When there are five global bidders, we do not reject the null hypothesis that revenue is similar between the two treatments (column (4): z=-1.251, p-value=0.2111).

Lastly, we look at the bidders' surplus measure. Within the same auction format, bidders' surplus is lower when there are more rival bidders. This observation is highly statistically significant and the difference is higher in the SimOnly treatment. In the SimOnly treatment, bidder surplus is lower by 19% (column (1): t=5.9204, p-value=0.0000). In the SimCom treatment, bidder surplus is lower by 14% (column (2): z=4.596, p-value=0.0000). Controlling for the number of bidders, we do not reject the null hypothesis that bidder surplus is similar between the two auction format (column (3): t=1.0935, p-value=0.2752; column (4): z=0.046, p-value=0.9630).

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[x] Prior to running the Wilcoxon ranksum test, we run the Shapiro-Wilk test and the Skewness and Kurtosis test to check whether parametric or non-parametric comparison of means is more suitable for the variable under analysis. When the parametric test is more suitable, we run the usual parametric F- and t- test for comparison of means.

Table 8: Summary Statistics of Performance Measures

	SimOnly (1)		SimCom (2)		Two Global Bidders (3)		Five Global Bidders (4)	
	SimOnly2	**SimOnly5**	**SimCom2**	**SimCom5**	**SimOnly2**	**SimCom2**	**SimOnly5**	**SimCom5**
Efficiency								
Number of Observations	132	60	132	66	132	132	60	66
Average	0.8957	0.9140	0.9607	0.9469	0.8957	0.9607	0.9140	0.9469
Median	1	1	1	1	1	1	1	1
Minimum Bid	0.4100	0.3741	0.3765	0.4029	0.4100	0.3765	0.3741	0.4029
Maximum Bid	1	1	1	1	1	1	1	1
Wilcoxon (Mann-Whitney) Test^{+}	0.738 (0.4606)		1.900 (0.0574)*		-3.573 (0.0004)**		-1.868 (0.0617)*	
Seller Revenue								
Number of Observations	132	60	132	66	132	132	60	66
Average	0.5880	0.8025	0.6945	0.8254	0.5880	0.6945	0.8025	0.8254
Median	0.5693	0.8156	0.6989	0.8387	0.5693	0.6989	0.8156	0.8387
Minimum Revenue	0.1783	0.5567	0.0789	0.4476	0.1783	0.0789	0.5567	0.4476
Maximum Revenue	1.0616	1.0140	1.2500	1.0274	1.0616	1.2500	1.0140	1.0274
Wilcoxon (Mann-Whitney) Test^{+}	-7.362 (0.0000)**		-4.336 (0.0000)**		t=-4.3057^ (0.0000)**		-1.251 (0.2111)	
Bidder Surplus								
Number of Observations	132	60	132	66	132	132	60	66
Average	0.3008	0.1121	0.2662	0.1305	0.3008	0.2662	0.1121	0.1305
Median	0.3198	0.1359	0.2767	0.1143	0.3198	0.2767	0.1359	0.1143
Minimum Payoff	-0.4394	-0.5105	-0.5741	-0.0889	-0.4394	-0.5741	-0.5105	-0.0889
Maximum Payoff	0.8217	0.4433	0.9211	0.5524	0.8217	0.9211	0.4433	0.5524
Wilcoxon (Mann-Whitney) Test^{+}	t=5.9204^ (0.0000)**		4.596 (0.0000)**		t=1.0935^ (0.2752)		0.046 (0.9630)	

Note

$^{+}$ We report the z-statistics. The p-values are reported in paranthesis.
^ Denotes parametric F tests and t tests
** denotes significance at the 5% level.
* denotes significance at the 10% level.

Key

SimOnly2 : Simultaneous-only auction with 2 global bidders.
SimOnly5 : Simultaneous-only auction with 5 global bidders.
SimCom2 : Simultaneous-combination auction with 2 global bidders.
SimCom5 : Simultaneous-combination auction with 5 global bidders.

6 Conclusion

How would a bidder react when there are more competitor bidders? When bidders demand only one object, bidders bid more aggressively to improve their chances of winning the object. When bidders have multiple-object demand with positive synergies, they face an "exposure" problem. If they bid above the stand-alone value for the individual object, they may make losses as they may not win all the objects to enjoy the synergies. Consequently, when there are more bidders, the probability of incurring losses increases. As a result, bidders are expected to bid *less* aggressively with more bidders.

When a seller has multiple objects for sale and there exists positive synergies for these objects, what is the optimal way to sell these objects? Should they be sold separately or as a package? By selling multiple objects in a package, bidders are certain to obtain the positive synergies associated with the objects. Thus, bidders would bid higher than the sum of the stand-alone value for the individual items. Therefore, sellers should expect higher efficiency and revenue with package bidding.

Our paper experimentally investigates the answers to the above two questions. Following the model of Krishna and Rosenthal (1996), we conduct a simultaneous second-price sealed-bid auction for two objects and allow bidders to have the option to submit bids for the two objects separately as well as bids for both objects as a package. Our results support the theoretical prediction Krishna and Rosenthal (1996) that bidders bid less aggressively with more bidders. When bidders do not have the option to bid for the package, they generally bid above the stand-alone value for the individual objects, but below the equilibrium value predicted by the theory. When bidders bid for both objects individually and have the additional option to bid for both objects as a package, they strategize their bids in favor of the package bid. We also find that efficiency and revenue are higher when the package bid is offered.

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