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Demand Reduction in Multi-Unit Auctions with Varying Number of Bidders and Units

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Abstract

We examine the effect of varying the number of bidders and units on bid values in multi-unit auctions. Our results suggest that the uniform-price auction is sensitive to demand reduction, however, increasing the number of bidders or/and units can significantly decrease it.

Key words: Multi-unit auctions; Demand reduction; Bidders' number; Units' number.
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An increasing number of products are being sold in auctions (Krishna, 2010). Hence, auctions are now an important way to organize markets. Although most of the theoretical work examines the sale of a single object, many of the most important auctions involve the simultaneous sale of multiple identical objects; the so called multi-unit auction (Swinkels, 2001). In multi-unit auctions, the most common mechanisms used in the empirical literature are the uniform-price and the multi-unit Vickrey auctions. The multi-unit Vickrey auction is a generalization of the single-unit second price auction. In this mechanism, the winner pays an amount corresponding to the sum of the bids (not his or her own) that are displaced by his or her successful bids (Krishna, 2010). As the clearing price is not based on the winner's bid but on the bids of the other participants, bidding truthfully is a dominant strategy in the multi-unit Vickrey auction (Engelbrecht-Wiggans, 1998). In spite of its demand-revealing property, the multi-unit Vickrey auction, however, is not popularly used in real auctions due to the complexity of its pricing rule (Engelbrecht-Wiggans et al. 2006).

In contrast, the uniform-price auction mechanism has been used more frequently due to its simpler pricing rule. All winners pay the same price which is equal to the highest rejected bid (Krishna, 2010). Nevertheless, the theoretical work by Engelbrecht-Wiggans and Kahn (1998) and Ausubel and Cramton (2002) indicated that uniform-price auctions can entail a potential problem related to the issue of "demand reduction". That is, since one of an individual's bids can determine the clearing price (i.e., he or she has to pay for infra-marginal units), the bidder has an incentive to bid less than his/her values for all units except for the first unit, which reduces the seller's revenue and induces economic inefficiencies. Hence, demand reduction in uniform-price auction is a serious concern that may generate strong inefficiencies and revenue losses. Few theoretical and empirical studies, however, have proposed solutions that could reduce demand reduction effects. Theoretically, Swinkels (2001) demonstrated that demand reduction on price reaches zero when the number of bidders and units is infinitely high. The use of infinite number of units and bidders in real multi-unit auctions is of course unrealistic. Engelbrecht-Wiggans et al. (2006) showed theoretically and empirically that for a fixed number of units, the incentives for demand reduction in second unit bids weakly decreased when the number of bidders increased but did not reach zero in the asymptotic limit. Nonetheless, it is possible that results may be different in auctions involving more than two units. For instance, in a two-unit setting, participants may reduce their second-unit bid as this bid can later determine the price that

the winner will pay. However, when the number of units is more than two (e.g., 4), we may expect higher second-unit bids as the auction price is now determined by a lower-unit bid (e.g., the fourth-unit bid).

To fill this void, we designed an experiment to check the effect of varying both the number of bidders (from 2 to10) and the number of units (from 2 to 4) on bidding behavior and demand reduction[2]. We vary both the number of bidders and units to evaluate the effect on demand reduction of: (1) increasing the number of bidders keeping the number of units fixed; (2) increasing the number of units keeping the number of bidders fixed; (3) increasing the number of both the bidders and units; and (4) increasing the number of bidders and decreasing the number of units or vice versa.

Experimental design

We designed an experiment to investigate the effect of varying the number of bidders and units on bid values and demand reduction in multi-unit auctions.[3] We conducted an equal number of uniform-price and multi-unit Vickrey auctions on identical packets (40g) of a product (i.e., organic chips). 160 undergraduate students were recruited and were randomly assigned to four treatments. In both mechanisms, we carried out ten sessions of two bidders and two units (2_2), ten sessions of two bidders and four units (2_4), two sessions of ten bidders and two units (10_2) and two sessions of ten bidders and four units (10_4). No subject participated in more than one session. We conducted the experiment in a computer lab using the z-tree software (Fischbacher, 2007). Table 1 shows the number of auctions run during the experiment.

We conducted the experiment using a three-step procedure. In step 1, participants were invited to a specific computer lab at a specific day and hour. After taking a seat and given a welcome address, each participant received an envelope which contained 10€ as compensation for their participation, his or her identification number (to be held in secret

[2] Compared with previous empirical studies on demand reduction, we did not just vary the number of units but we also doubled the number of bidders (i.e., 5 bidders in Engelbrecht-Wiggans et al. (2006) vs. 10 bidders in our case).

[3] Past theoretical studies (e.g., Engelbrecht-Wiggans and Kahn, 1998; Ausubel and Cramton, 2002) have shown that multi-unit Vickrey auction is demand revealing for all auctioned unit. Due to its demand revealing property, we run our experiment following the homegrown value setting of List and Lucking-Reiley (2000) and Engelbrecht-Wiggans et al. (2006) considering bids obtained in the multi-unit Vickrey auction as an approximation of individual's true valuations and, therefore, we use it as a reference mechanism.

during the process) and a questionnaire designed to collect information on participants' socio-demographic characteristics. In step 2, we gave each participant a printed material that included an explanation of how the auction works and some examples to illustrate the auction. The instructions were identical across all treatments except for auction type and number of bidders and units. Given the importance of this step, we informed participants that it is very important that they fully understand the auction mechanism. Finally, to further permit a better understanding of the auction mechanism and a good familiarity with the software, we carried out a training session. Once we were certain that all subjects fully understood the auction mechanism and procedures, in step 3, participants were allowed to inspect the product and, then, each one of them was asked to submit, via the computer, how much she/he is willing-to-pay for each auctioned unit. Once all participants finished reporting their bids, the software determined whether the participant was the winner or not and the price that he/she had to pay for each unit won. Once the results were announced, the experiment ended by handing the product to the winner(s) who had to pay the corresponding market-clearing price. In the analysis, we used the Fisher-Pitman permutation test for independent samples due to sample size considerations.

Results and Discussion

In accordance with the aforementioned theoretical prediction, our results (in columns 2, 3 and 4 of Table 2) show that the first-unit bids in the multi-unit Vickrey auction and the uniform-price auction are not significantly different. Furthermore, the results exhibited in the third and the fourth column of Table 3 suggests that, in both mechanisms, the increase of the number of bidders and/or units did not affect the first-unit bids.

Our results in columns 5 and 6 of Table 2 are generally consistent with the aforementioned theory on demand reduction. In fact, we found that, in treatment 2_2, the second-unit bid is significantly lower in the uniform-price auction than in multi-unit Vickrey auction. However, the possible demand reduction found in treatment 2_2 was not found in the other treatment and seems to have been mitigated by the increase of the number of bidders or/and units. This explanation is confirmed by the results displayed in columns 5 and 6 of Table 3. In fact, we found that the variation of the number of bidders or/and units did not affect the second-unit bid in the multi-unit Vickrey auction possibly because of the incentive compatibility of this auction mechanism. Nonetheless, in the uniform-price auction and taking as a base the 2 units - 2 bidders scenario, the results show that an increase in the

number of bidders (units) from 2 to 10 (2 to 4) led to a significant increase in the average of the second-unit bids from 0.52€ to 0.84€ (0.52€ to 0.72€). We also found that jointly increasing the number of bidders and units yielded significantly higher second-unit bids than those observed in a 2-bidder and 2-unit setting (0.82€ versus 0.52€) in the uniform-price auction. However, keeping fixed the number of units at 4 and increasing the number of bidders from 2 to 10 did not significantly change participants' second-unit bids in both mechanisms.

Overall, our results suggest three strategies[4] that can be used to reduce demand reduction effects on second-unit bids in uniform-price auctions: 1) increasing the number of bidders (which could increase the level of competitiveness), 2) increasing the number of units (which could affect the probability of winning the second unit); and 3) increasing both the number of bidders and units (being the number of bidders higher than the number of units). Interestingly, our results suggest that an auctioneer in a uniform-price auction can afford to be indifferent between increasing the number of bidders and increasing the number of units (i.e. treatment 2_4 versus treatment 10_2). This result has an important implication for users of uniform-price auction in lab or field experiments. Carrying out a uniform-price auction with a high number of participants just to reduce demand reduction can significantly increase experimental costs. Another option that could reduce demand reduction but would not significantly increase experimental costs is to carry out uniform-price auction with a high number of auctioned units.

Since the fourth-unit bids are the bids that are more likely to determine the clearing price in treatment 2_4 and 10_4, we predict more demand reduction in this bid and a positive effect of the increase of the number of bidders, especially, in the uniform-price auction. As expected, the results exhibited in columns 8 to 10 of table 2 suggest an absence of demand reduction in the third-unit bids. However, we found significantly lower fourth-unit bids, in treatment 2_4, in the uniform-price auction than in the multi-unit Vickrey auction. Interestingly, the bids for the fourth unit in both auction mechanisms are not statistically different when the number of bidders is equal to 10. Results displayed in columns 9 and 10 of table 3, showed that increasing the number of bidders significantly increased the fourth-unit

[4] The first strategy was also suggested by Engelbrecht-Wiggans et al. (2006), the two other strategies, however, are based on the present work.

bids in the uniform price auction and, hence, mitigated the demand reduction found in treatment 2_4.

Conclusion

Our study analyzed the sensitivity of demand reduction to greater number of bidders and units. Our work suggests a number of important points. First, consistent with previous empirical studies, we found that the uniform-price auction (multi-unit Vickrey auction) is sensitive (not sensitive) to demand reduction. Departing from a setting of equal number of units and bidders, our results suggest that an increase in the competitiveness level (i.e., increasing the number of bidders) or the probability of winning (i.e., increasing the number of units) can decrease demand reduction in uniform-price auction. Therefore, in accordance with the theoretical findings of Swinkels (2001), it seems that running uniform-price auctions with relatively large number of bidders and units can be useful in reducing demand reduction effects. Our results also showed that an increase in the number of bidders can significantly increase only the bids for the units that are more likely to determine the clearing price (i.e., bid for the last units).

In summary, while demand reduction seems to be a major obstacle that limits the application of uniform-price auction not only as a mechanism to allocate products and services but also as a value elicitation method, this can be remedied by generally increasing the number bidders and/or units in the auctions.

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Table 1. Experimental Treatments

Treatment	Bidders per auction	Units per auction	Multi-unit Vickrey auction sessions	Uniform price auction sessions	Total subjects
2_2	2	2	10	10	40
2_4	2	4	10	10	40
10_2	10	2	2	2	40
10_4	10	4	2	2	40

Table 2. Average Bids

Treatment	Bid1			Bid 2			Bid 3			Bid 4		
	Vickrey	Uniform	p-value	Vickrey	Uniform	p-value	Vickrey	Uniform	p-value	Vickrey	Uniform	p-value
10_2	1.09	1.05	0.79	0.96	0.84	0.55	-	-	-	-	-	-
10_4	1.04	0.94	0.33	0.92	0.82	0.39	0.71	0.57	0.25	0.52	0.38	0.25
2_2	0.89	0.80	0.40	0.73	0.52	**0.04**	-	-	-	-	-	-
2_4	0.94	0.87	0.62	0.76	0.72	0.68	0.56	0.44	0.21	0.42	0.23	**0.04**

Table 3. Effect of Varying the Number of Bidders and the Number of Units on Bids

Auction format	Treatment	Bid 1	p-value	Bid 2	p-value	Bid 3	p-value	Bid 4	p-value
Vickrey	2_2 to 10_2	0.89 to 1.09	0.18	0.73 to 0.96	0.17	-	-	-	-
	2_4 to 10_4	0.94 to 1.04	0.42	0.76 to 0.92	0.15	0.56 to 0.62	0.11	0.36 to 0.53	0.29
	2_2 to 2_4	0.89 to 0.94	0.72	0.73 to 0.76	0.34	-	-	-	-
	10_2 to 10_4	1.09 to 1.04	0.69	0.96 to 0.92	0.77	-	-	-	-
	2_4 to 10_2	0.94 to 1.09	0.30	0.76 to 0.96	0.20	-	-	-	-
	2_2 to 10_4	0.89 to 1.04	0.25	0.73 to 0.92	0.12	-	-	-	-
Uniform	2_2 to 10_2	0.80 to 1.04	0.10	0.52 to 0.84	**0.03**	-	-	-	-
	2_4 to 10_4	0.87 to 0.94	0.57	0.72 to 0.82	0.36	0.35 to 0.43	0.26	0.23 to 0.38	0.22
	2_2 to 2_4	0.80 to 0.87	0.48	0.52 to 0.72	**0.02**	-	-	-	-
	10_2 to 10_4	1.04 to 0.94	0.52	0.84 to 0.82	0.89	-	-	-	-
	2_4 to 10_2	0.87 to 1.04	0.32	0.72 to 0.84	0.44	-	-	-	-
	2_2 to 10_4	0.80 to 0.94	0.09	0.52 to 0.82	**0.01**	-	-	-	-