1-25-2024

When Online Auction Meets Virtual Reality: An Empirical Investigation

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ABSTRACT

The online auction is becoming increasingly popular in e-commerce, which allows to sell a product to the buyer with the highest bid. However, the lack of authentic product details for a thorough evaluation still poses challenges to its success. Recently, virtual reality (VR) is introduced to online auctions. We employ a unique dataset to investigate the effects of VR on auction outcomes and bidding activities. Results show that VR enhances buyers' bidding competition, which in turn increases auction success and price, resulting in a competitive effect. Additionally, we find VR boosts buyers' strategic responses to the bidding war, leading to a late-bidding effect. Findings contribute to both the theory and practice of VR and online auctions in selling houses.

Keywords

Online auctions, virtual reality, bidding competition, late bidding, auction success, auction price.

INTRODUCTION

In recent years, online auctions (also known as Internet auctions) have been used to sell a wide range of goods, such as houses, cars, and artwork. Unlike the posted price approach, where sellers set a fixed product price, online auctions allow buyers to compete for an item by offering bids before the auction's closing time (Wang, 1993). Eventually, the buyer of the highest bid can purchase the item at his or her last bid, which is the product's final price. Through online auctions, products can be sold to the person with the highest willingness to pay, improving the seller's revenue (Chan et al., 2007).

However, one critical challenge of the online market is high product uncertainty (Dimoka et al., 2012). Given the separation of goods and buyers on the Internet, buyers cannot directly examine product quality in person, like in an offline store. Traditional online product presentation tools, such as text, pictures, and videos, are difficult to demonstrate stereo information. The lack of product details may raise buyers' uncertainty concerns, making them hesitant to participate in auctions and bid conservatively. And such concern may become severe for houses (typical high involvement products) due to their high product value and extreme importance (Traylor, 1981).

Recently, the emerging virtual reality (VR) technology has been introduced to online house auctions. The emerging VR function can generate a simulated three-dimensional (3D) visual reproduction of realistic settings (Steuer, 1992). This function allows users to explore a house's characteristics on a computer screen and change their viewing orientations through real-time interactions.

Extant online auction literature has identified that money-back guarantees, textual product descriptions, and picture postings can influence bidders' participation, bidding amount, and early bidding (Li et al., 2009). However, regarding the novel VR technology, there are few works that have investigated VR's effects on online auction performance. This study aims to fill this gap by addressing the research question: 1) How does VR affect the outcomes of online auctions in selling houses? 2) How does VR influence buyers' bidding activities?

We collect a unique dataset from the largest auction platform in China and conduct empirical analysis to examine VR's effects in online auctions. Results reveal that VR can lead to aggressive bidding competition, i.e., a competitive effect. That ultimately improves auction success and the final selling price. To prevent the winners' curse (the winner overestimates the value of a product and overpays to obtain it), bidders will strategically bid late to avoid a bidding war, leading to a late-bidding effect. In sum, VR can improve the effectiveness of online auctions and increase sellers' revenue. Our findings offer theoretical insights into the literature on VR and online auctions and provide implications for stakeholders in online auctions.

LITERATURE REVIEW

Virtual Reality

Previous literature shows that VR has higher vividness and interactivity in contrast to traditional audio and pictorial tools (Steuer, 1992). The impact of VR has been examined in broad fields (Dincelli & Yayla, 2022), including online virtual games (Shin, 2009), healthcare (Smith et al., 2020), education (Radianti et al., 2020), and tourism (Bogicevic et al., 2019). Additionally, retailing is also a main context of using VR. There is also a stream of literature investigating VR's influences in retailing. For instance, Pfeiffer et al., (2020) reveal that consumers' information search behavior in VR is similar to that in physical stores. VR can enhance

consumers' information search and reduce their time spending on evaluating alternatives (Sihi, 2018). Additionally, VR can increase consumers' perceived diagnosticity and flow (Jiang & Benbasat, 2004) and influence consumers' intentions of returning to a website and making a product purchase (Jiang & Benbasat, 2007).

Online Auction

Prior studies have identified a series of factors that can influence auction success and the final selling price (Ducarroz et al., 2016; Gilkeson & Reynolds, 2003). These factors can be categorized into three types: (1) product characteristics, such as product certification and reference price; (2) product presentation, such as its format and information richness; and (3) auction features, including duration, ending rule, start price, reserve price, and entry fees. As a new type of product presentation technology, in this study, we conduct an empirical analysis to understand how VR influences the success and price of online auctions.

Buyers' Bidding

Bidding competition reflects buyers' participation intensity in the bidding process to compete for the product (Gregg & Walczak, 2008), which can be measured by the number of bidders and bids. On one side, intense bidding competition can lead to a high closing price (Ducarroz et al., 2016), improving sellers' revenue and online auction effectiveness. On the other side, increased competition may also induce a bidding war and raise the concern of the "winners' curse."

As a strategic response to the bidding war, buyers may tend to use late bidding. Late bidding, also known as last-minute bidding or snipe, refers to the practice of placing bids right before the closing time (Roth & Ockenfels, 2002). Late bidding is proven to be an effective strategy for buyers to deprive the rival's time to respond, shed their private information about product value, and soften the fierce competition to avoid a bidding war (Roth & Ockenfels, 2002; Wintr, 2008).

Based on above literature review, we aim to understand the influence of VR on auction outcomes and reveal the mechanism through examining its effects on bidding activities. Figure 2 shows the conceptual framework.

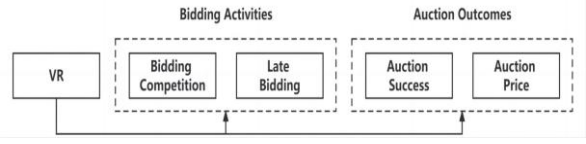

Figure 2. Research Framework

EMPIRICAL FRAMEWORK

Research Context

Our research context is Ali Auction, the largest online auction platform in China (similar to other popular auction platforms like eBay and Amazon in US), with a total transaction volume exceeding 500 billion CNY in 2018. Potential buyers can browse the items and pay a refundable deposit to enroll in the auction. During the auction, enrolled buyers can place bids to compete for the auction item. Bidding follows the English auction paradigm. The auction platform adopts a "soft close" mechanism, which will automatically extend the bidding time by five minutes if a new bid is placed before the closing time.

Virtual Reality

On the target platform, the novel VR technology has been employed in online house auctions to present product details. VR provides potential buyers with an interactive experience and 360-degree panoramic views to examine a house. For instance, if a house supports the VR function, the seller captures comprehensive details using a camera or panorama scanner in that house. Then, the collected imagery content is reconstructed into a simulated 3D model using computer vision techniques. The 3D model is a point-to-point reproduction of the house's visual content on the computer. Afterward, potential buyers may utilize the VR interface to explore the house's size, internal decoration, and spatial structure and layout on a screen. Users can also change their locations and orientations to obtain 360-degree views by interacting with the VR interface using a mouse. Compared to pictures and videos, the interactive experience of VR has a strong potential to better satisfy buyers' needs in obtaining house information.

Data

Our dataset contains online house auction records from six different cities in China. We exclude auction records that are suspended or withdrawn by the seller and only keep records that complete the entire auction process. Houses are either successfully auctioned (i.e., one bidder wins the auction) or fail (i.e., no bids). Finally, we collect a dataset of 36,240 online house auction records, among which 20,232 houses are successfully auctioned and 7,643 houses support the VR function. Table 1 reports variable descriptions. Table 2 shows summary statistics.

Variable	Description
AuctionSuccess	Whether an auction is successful.
AuctionPrice	The final selling price (in CNY).
NumBids	The number of bids in an auction.
NumBidders	The number of bidders in an auction.
BidsLast60Min	The number of bids in the last 60 minutes.
NumExtensions	The number of extensions before closing.
VR	Whether VR supports (1) or not (0).
Size	The area of a house (in m^2).
StartingPrice	The number of opening bid price.
Deposit	The number of deposits of an auction.
Valuation	The valuation price of the product.
Increment	The minimum bidding increments.
Guarantee	Whether money-back guarantee supports.
Video	Whether supports video (1) or not (0).
NumPictures	The number of pictures.
NumText	The number of word descriptions.

Table 1. Variable Descriptions

Variable	N	Mean	Min	Max
AuctionSuccess	36240	.558	0	1
AuctionPrice	20232	2245419.2	6200	1.029e+08
NumBids	20232	49.319	1	695
NumBidders	20232	4.961	1	37
BidsLast60Min	20232	25.988	0	410
NumExtensions	20232	38.282	0	610
VR	36240	.211	0	1
Size	36240	265.179	2.1	3000125.5
StartingPrice	36240	1613245	1	2.537e+08
Deposit	36240	240859.51	1000	47000000
Valuation	36240	2221761.9	89	3.358e+08
Increment	36240	7597.534	1	1200000
Guarantee	36240	.387	0	1
Video	36240	.395	0	1
NumPictures	36240	11.952	2	21
NumText	36240	5162.219	263	12173

Table 2. Summary Statistics

Identification

In this study, the primary concern for identification is sellers' strategic adoption of VR. Specifically, whether a house supports VR is not random but determined by its attributes and the seller's preference.

To enhance identification, we employ propensity score matching (PSM) (Rosenbaum & Rubin, 1983) to mitigate the selection bias from observables. Specifically, we match all observed control variables using the PSM nearest neighborhood algorithm (n=4) to generate the matched sample. Afterward, we conduct balance checks and find that the mean absolute bias reduces from 11.4% (before match) to 1.9% (after match). Besides, we draw the density plot of propensity scores in Figure 1 and find that the overlap assumption is also satisfied.

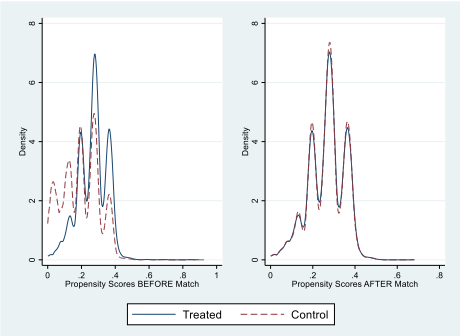

Figure 1. The Density Plot of Propensity Scores

Additionally, we also address the hidden bias from unobservables using the instrumental variable (IV) approach. Particularly, we employ the VR adoption rate of former closed auctions in the same city (*ClosedVRRate*) as the instrument for the endogenous VR choice of the latter new auction. The idea is as follows. First, VR services are similar in the same city. When a new seller decides to sell a house on the platform, his/her choice of VR may be influenced by the VR adoption status of previous sellers. Thus, *ClosedVRRate* satisfies the relevance condition. Second, buyers base on the latter house's product information to determine the valuation and submit bids. Whether the former closed auctions adopt VR or not may not directly affect buyers' valuations in the latter auction. Thus, *ClosedVRRate* does not affect the new house's auction outcomes or bidding activities, satisfying the exclusion restriction. In this study, we employ both PSM and IV methods to mitigate the selection bias of VR in estimations.

MODEL AND RESULT

VR on Auction Outcomes

Auction Success

We analyze the effect of VR on auction success using a *Probit* model. Specifically, the model specification is as follows:

$$Probit(AuctionSuccess_i) = \beta_0 + \beta_1 VR_i + \beta_c \boldsymbol{Controls_i} + \varepsilon_i, (1)$$

where VR_i is also a binary indicator, equal to 1 if VR supports the auction item i or 0 otherwise. To exclude confounding factors that may influence bidding competition, we account for a set of $Controls_i$ including $Size_i, StartingPrice_i, Deposit_i, Valuation_i, Increment_i, Gurantee_i, Video_i, NumPictures_i,$ and $NumText_i$. Besides, we also include *City* and *Month* dummies to control for location and time fixed effects.

The result is reported in Table 3, column (1). The coefficient of VR is positive (2.265) and statistically significant ($p < 0.01$) on auction success. This indicates auction items that employ VR are more likely to be sold.

The information asymmetry between sellers and buyers is the primary concern that hinders a successful auction transaction. Potential buyers face high-level valuation uncertainty and will be reluctant to participate in auctions (Hong et al., 2016). Our finding reveals that the novel VR can increase the possibility of asset liquidation and improve online auction effectiveness, demonstrating VR's strong potential in facilitating online auctions.

Auction Price

Another key outcome is auction price, which refers to the final price that the buyer pays for the item. The auction price of the i^{th} auctioned item (i.e., $AuctionPrice_i$) is determined by the competitive bidding of potential buyers. Eventually, the bidder who offers the highest bid wins the auction and pays his/her last bid as the price. We employ the log-linear model to investigate the influence of VR on auction price. Specifically, the model specification is:

$$ln(AuctionPrice_i) = \beta_0 + \beta_1 VR_i + \beta_c \boldsymbol{Controls_i} + \varepsilon_i, (2)$$

where VR_i and $\boldsymbol{Controls_i}$ are the same set of independent variables as those in Equation (1). The result is reported in Table 3, column (2). The coefficient of VR is positive (0.241) and significant ($p < 0.01$), suggesting that VR can increase the final price of an auction item. In other words, our finding shows that sellers can benefit from VR to increase the revenue.

	(1) AuctionSuccess	(2) AuctionPrice
VR	2.265***	0.241***
	(0.009)	(0.090)
Constant	-0.433***	13.161***
	(0.082)	(0.077)
Controls	Yes	Yes
City, Month FE	Yes	Yes
Observations	22,577	15,190

Table 3. The Effect of VR on Auction Outcomes

VR on Bidding Activities

Bidding Competition

Bidding competition refers to the intensity of outbidding for the item. We measure bidding competition with (1) *NumBidders*, the number of bidders, and (2) *NumBids*, the number of bids. If additional participants join the bidding process, the bidding competition becomes fiercer. Bidders can increase the number of bids to improve their chances of winning the auction. Hence, an increased bid number also indicates a higher level of bidding competition.

We focus on successful auctions (with at least one bid) and utilize the log-linear model to examine the impact of VR on bidding competition. The model specification is:

$$ln(BiddingCompetition_i) = \beta_0 + \beta_1 VR_i + \beta_c \boldsymbol{Controls_i} + \varepsilon_i, (3)$$

where VR_i and $\boldsymbol{Controls_i}$ are the same set of independent variables as those in Equation (1). Table 4, columns (1) & (2) report the results of VR in the bidding competition. We find that the coefficients of VR are both significant and positive on the number of bids (2.147, p<0.01) and bidders (0.631, p<0.01). The finding suggests that VR technology may encourage additional buyers to participate in online auctions. Bidders will become more active in submitting bids if the item supports VR.

In our research context, VR offers a new channel for buyers to obtain public information about auction items. This helps to reduce buyers' valuation costs and alleviate their product quality concerns. As a result, potential buyers are willing to engage in the bidding competition. Our result reveals that VR can bring a competitive effect to online auctions. Increased bidding competition also contributes to an improved final auction price.

	(1) NumBids	(2) NumBidders
VR	2.147***	0.631***
	(0.274)	(0.107)
Constant	2.443***	1.320***
	(0.157)	(0.060)
Controls	Yes	Yes
City, Month FE	Yes	Yes
Observations	15,190	15,190

Table 4. The Effect of VR on Bidding Competition

Late Bidding

Late bidding is used by buyers to outbid their competitors and secure the item for themselves without incurring a bidding war (Ockenfels & Roth, 2006) and also protect bidders' private information and prevent competitors from learning their valuation (Roth & Ockenfels, 2002).

In online auctions, we argue that VR may generate two competing effects on late bidding. On one hand, rational bidders may strategically bid late to avoid the "bidding war", preventing them from winning the item at a high price, i.e., the "winners' curse" (Bajari & Hortacsu, 2003). VR provides additional information about the item, reduces the cost of valuation, and drives up bidding competition. Thus, from the perspective of "avoiding a bidding war", we expect VR to enhance late bidding.

However, on the other hand, buyers rely on both public and private information to determine the item's valuation. VR provides more public product information to all bidders. In that sense, bidders' private information becomes less important for their item valuation. For VR-enabled auctions, bidders have less urgency to protect their private information through late bidding compared to non-VR auctions. Thus, we also expect VR to reduce buyers' late bidding due to the reduced private information protection.

To test for the competing effects of VR on late bidding, we use (1) *BidsLast60Min*, the number of bids during the last 60 minutes before the closing time, and (2) *NumExtensions*, the number of extensions to the auction's closing time to measure late bidding. We employ the log-linear model for analysis, where the specification is:

$$ln(LateBidding_i) = \beta_0 + \beta_1 VR_i + \beta_c \boldsymbol{Controls_i} + \varepsilon_i, (4)$$

where VR_i is also a binary variable of our primary interest, indicating whether the item i supports VR (1) or not (0). We include the same set of $\boldsymbol{Controls_i}$ as those in Equation (1) to exclude the effect of confounders.

We report the estimation results in Table 5, columns (1) & (2). The coefficients of VR are significant and positive on *BidsLast60Min* (2.061, p<0.01) and *NumExtensions* (2.542, p<0.01), indicating that VR encourages late bidding.

The finding supports the "avoiding the bidding war" hypothesis. That is, as a strategic response to the enhanced competition induced by VR, auction participants tend to bid late to reduce the chance of trapping themselves into a bidding war, avoiding the "winners' curse" issue.

	(1) BidsLast60Min	(2) NumExtensions
VR	2.061***	2.542***
	(0.252)	(0.310)
Constant	2.041***	1.911***
	(0.147)	(0.178)
Controls	Yes	Yes
City, Month FE	Yes	Yes
Observations	15,190	15,190

Table 5. The Effect of VR on Late Bidding

CONCLUSION

This study contributes to knowledge in several ways. To begin with, it adds to the growing literature on VR by providing the very first evidence to explain its effects in online auctions. We find that the rich product information offered by VR can improve the effectiveness of online auction transactions, increasing both auction success and price. Second, this work also contributes to the literature on online auctions by revealing VR's effects in buyers' bidding behaviors. VR leads to a competitive effect and a late-bidding effect in the context of selling houses. This study also provides managerial implications for both auction platforms and sellers.

ACKNOWLEDGE

This project is sponsored by Shanghai Pujiang Program.

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