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Interfaces with Other Disciplines

Analysis and design for multi-unit online auctions

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ABSTRACT

By incorporating platform fees and bidders' stochastic arrival process into the analysis of the multi-unit Vickrey auctions, we examine the performance of the two popular selling mechanisms (posted price and auction) on the Internet, characterize and derive the closed-form solution for the optimal lot-sizing policies. We show that the seller prefers auctions rather than posted price selling only when the valuation dispersion and the Web traffic are both sufficiently large. The theory also implies that there is no dominant selling mechanism. Since it is not always beneficial for the seller to auction more goods in a single auction, we further derive the optimal number of auction the seller should run and the optimal number of units to be sold in each auction. Moreover, we consider how to reconcile the conflict interests between the seller and the auction platform in single period and multi-period auctions respectively. Our main results indicate that, to decrease the listing fees, increase commission ratio and shorten the auction duration are all helpful for the platform to coordinate its interests with that of the seller.

1. Introduction

Online auctions have become increasingly popular for selling a growing number of products and services. However, the functional and operational characteristics of online auctions are very different when compared to traditional offline auctions (to take a close look at traditional auction theory, see for example, Ghate, 2015; Krishna, 2010; Maskin and Riley, 2000; Myerson, 1981). Unlike traditional auctions, online auctioneers such as eBay and Amazon operate as unaligned third parties, creating a virtual auction platform for the auction users (i.e., buyers and sellers) to meet and conduct purchase transactions. Other examples of retail auction platforms include Liquidation.com, eBid.net, uBid.com, bidz.com, CQout.com, Quibids.com, bidcactus.com, and skoreit.com (Ghate, 2015). An auction platform generates revenue through the fees it collects from the sellers in exchange for auction listing and other services it provides. Auction platform fees, which usually include listing fees and commission fees,[1] are therefore critical design parameters for a platform's sustainability and growth. The function served by the platform and its fees for the seller and its consequence (especially its effect on lot sizes) deserve further investigation.

Traditional auctions start with a fixed number of bidders, often requiring a screening process, and once the auction begins no new bidders may join (Kwasnica & Sherstyuk, 2013). In online auctions bidders arrive the website at random and often submit bids very close to the ending time (a practice known as sniping).[2] Uncertainty in the bidders' arrival process and that in Web traffic increases decision complexity, especially when we explore the seller's choice between the two conventional sales mechanisms (auction and posted price). For instance, posted price selling may be preferred by the seller instead of auctions due to insufficient Web traffic (see detailed analysis in Section 4.2). In addition, it is generally not optimal for the seller to offer the whole lot in a single auction, so he often needs to hold a series of sequential auctions to maximize his total profit (Chen, Ghate, & Tripathi, 2011; Pinker, Seidmann, & Vakrat, 2010). In this case, we must investigate how many sequential auctions should be conducted and how many units should the seller offer in each auction. Lot-sizes, that is, the number of identical units to be offered in each auction, which have been ignored in traditional auctions, are also key decision variables in online auctions.

Compared to traditional offline auctions, online auctions allow the auctioneer a significantly broader choice of auction design parameters, which include, selling mechanisms, auction platform charges, the number of auctions to run, the lot size that is offered for sale in each auction, etc.[3] Furthermore, we believe that the bid-

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[1] See detailed analysis in Section 3.

[2] Sniping, also referred as last-minute bidding, implies that the last minute bidders wait until the very last moment as the chances of being outbid decrease with the time left in the auction. The phenomenon of sniping has recently received extensive theoretical and empirical attention (Ariely et al., 2005; Ely & Hossain, 2009; Roth & Ockenfels, 2002).

[3] All auction design parameters listed have been studied in existing literature except auction platform charge.

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ders' stochastic arrival process and the dynamic Web traffic need to be considered in the design analysis. These considerations motivate us to focus on understanding the impact of new decision variables and new circumstances on optimally designing the multi-unit online auctions.

Specifically, this paper develops a general analysis framework for the design of multi-unit online auction in single- and multi-period respectively in which a seller seeks to sell off an initial inventory of identical items via a multi-unit Vickrey auction mechanism.[4] Bidders are assumed to arrive at the auction according to a non-stationary Poisson process. Since the online auction is a fundamentally different way of selling goods and managing inventory from the posted-price mechanism,[5] we explore conditions when a seller listed the same items by auction and by posted price. Contrary to conventional wisdom (Vakrat & Seidmann, 1999a, 1999b; Wang, 1993, 1998) that goods with wider valuation dispersion are more suitable to be auctioned off, we show that the seller is strictly better off from auction than posted price only when the Web traffic and valuation dispersion are both sufficiently large. We find that there does not exist a dominant sale format. Auctions are conducive to price discovery for used and idiosyncratic items with large valuation dispersion under the precondition that the Web traffic is sufficiently large.[6] The results therefore imply that both heterogeneity across bidders and dynamic change of Web traffic can account for the coexistence of the two mechanisms (auction and posted price). In principle, our results might help to explain why a seller might want to offer both sale formats as a way to cater to heterogeneity in valuation dispersion of buyers and as a response to uncertainty in Web traffic.[7]

Obviously, offering a large lot in a single auction will have negative impact on the auction price. The seller can split the whole lot into multiple sequential online auctions to maximize his total profit. By solving a dynamic programming formulation, we derive the optimal number of auctions the seller should run and the optimal lot-size to offer in each period. We find that, in the presence of listing fees and commissions, the optimal lot-size is not identical in each period but drops from period to period to save on the total variable costs incurred by running sequential auctions. Moreover, we take the online auction site as an independent auction platform and investigate how to reconcile the conflict interests between the seller and the platform in single period and multi-period auctions respectively. Interestingly, we find that the platform can take some effective measures to coordinate its interests with that of the seller, which include decreasing the listing fees, increasing commission ratio and shortening the auction duration.

We do not intend our model to serve as a decision tool that provides precise calculation of the results of multi-unit online auctions, but rather, we seek to demonstrate some managerial insights. This paper contributes to the literature by enhancing the conceptualization of the traditional theory of auction-based mercantile processes in the online context. Specifically, by incorporating some salient but ignored features (i.e., auction platform fees and dynamic Web traffic, as detailed above) into multi-unit online auction model, we try to gain some insights into the following issues:

(1) What effects does the valuation dispersion of goods have on auction closing prices? Is it the same as the result from existing research (Vakrat & Seidmann, 1999a, 1999b; Wang, 1993, 1998) that simply has a positive correlation? Once we consider the auction platform's Web traffic, what changes will be brought?
(2) Under what conditions would a seller find a posted price be more attractive than an auction, particularly when we take into account the heterogeneity in buyers' valuation and uncertainty in Web traffic? What tradeoffs will the seller face with when optimally selecting one of two selling mechanisms?
(3) How can the seller design a series of sequential auctions to maximize his total profit? What are the tradeoffs associated with running more or fewer auctions? Are there an optimal number of auctions that the seller should conduct? Given the optimal number of periods, what is the optimal lot size to offer in each period?
(4) Once considered the fees charged by the auction platform, what kind of inconsistency emerges between the platform and the seller's objectives? How to coordinate this inconsistency by adjusting some design parameters?

Compared to existing literature, we make two contributions. First, when comparing the relative performance of different selling mechanisms, existing literature focus either on bidders' valuation distribution or agents' attitude towards risk. We find that Web traffic is also an important factor the seller has to consider when choosing the optimal mechanism. Second, we are the first to introduce platform fees to investigate optimal lot-sizing policy and show how the platform designs the fee structure to reconcile its conflict interests with that of the seller.

Our paper proceeds as follows. In Section 2, we briefly review some of the relevant literature. In Section 3, we establish the benchmark model of multi-unit online auctions. In Section 4, we investigate the design of single-period online auction with bidders' stochastic arrival process, involving the comparative analysis of auction and posted price selling, the impact of valuation dispersion and Web traffic on auction price, and revenue analysis of the auction platform. Section 5 is the analysis for the design of multi-period online auctions. We adopt the method of dynamic programming to derive the optimal number of auctions to conduct and the optimal lot size to be offered in each period for the seller and the platform respectively. In addition, we explore how to reconcile the conflict interests between the two parties. Section 6 concludes the paper with some future research directions. All proofs can be found in the appendix.

2. Literature review and our contributions

There are two streams of related research. The first stream compares the profitability of different selling mechanisms, i.e., auctions vs. posted price and (pure) auctions without a buy-now price vs. auctions with a buy-now price.[8] The second stream explores the

[4] Based on empirical analysis by Vakrat and Seidmann (2000) and further theoretical investigations in Bapna et al. (2008), Pinker et al. (2003, 2010), and Tripathi et al. (2009), a sequence of multi-unit auctions of identical items is observed to be the operational norm adopted by most online auction platform.

[5] Under posted-price mechanism, the seller presets a fixed price to maximize its expected profit and this fixed price is not generated by the bidding process.

[6] Distinguishing between more or less idiosyncratic items helps explain why auctions are more or less prevalent across broad product categories. For instance, auctions are much more common in selling collectibles or clothing, whereas posted prices are much more common for selling electronics or computers

[7] The simultaneous use of these two mechanisms (posted price and auctions) by a single firm and for the same product has grown with the commercialization and widespread use of the Internet. Examples of such practice include Dell Computer and IBM, both manufacturers and direct sellers of computer equipment, and uBid, which is an online reseller. In addition, there are many small online retailers on eBay that offer a posted pricing scheme and a multi-unit auction simultaneously. Finally, another way of combining posted price and auctions is the BIN option, which is available at most major online auction platforms.

[8] Buy-now price is also referred as buyout price, while on eBay it is BUY IT NOW (BIN) option. When a buyer chooses a BIN price in a listing, he can purchase the item right away at a presented price without participating into the bidding process. For an eBay-type auction, whether the BIN option disappears after the first bid is placed depends on the category the seller is listing in. In some eBay categories,

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