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Interfaces with Other Disciplines

Design of discrete Dutch auctions with consideration of time

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ABSTRACT

As a departure from much of the existing literature that aims at maximizing the expected revenue from a single auction, this research work is concerned with the design of discrete Dutch auctions to achieve the optimal balance between the selling price of the object and the auction duration so that the auctioneer's expected revenue per unit of time is as high as possible. The new objective is especially important in trading perishable products or services when multiple auctions are to be conducted by the auctioneer for different sellers during a limited period of time. Our findings indicate that the proposed discrete Dutch auction models generate higher average revenues per unit of time for the auctioneer than their counterparts without consideration of time. This is achieved by reducing the duration of each auction in exchange for more auctions to be held within the given time frame so that the small decrease in the revenues from the longer auctions is more than compensated for by the large increase in the total revenues from the shorter auctions. The numerical results show that the proposed discrete Dutch auction design becomes extremely useful when the number of bidders becomes large. It is also shown that complete knowledge about the number of bidders in the auction results in a higher auctioneer's expected revenue per unit of time.

1. Introduction

1.1. Dutch auctions

The Dutch auction is also known as a clock auction or an open-outcry descending-price auction, where the bid price is controlled by the auctioneer and displayed on a clock-like screen at the front of the auction site. Unlike the case in a traditional English auction in which the bid price increases over time, the auctioneer in a Dutch auction starts with an extremely high asking price and continues to lower it according to a predetermined schedule until a bidder indicates the willingness to pay by pushing a button at the desk in the auction room or calling out "mine".

Compared with the English auction where bidders continually push the price up, the Dutch auction is closed immediately after a bid is received, which results in a faster business transaction (van Heck, 2000). It is a popular way to sell perishable products or services whose value decreases with time such as fresh produce, plane tickets, hotel rooms, seasonal goods, concert tickets, and container space on ocean-going vessels among others. The Dutch auction has also been used for centuries to sell tulip and other plants in the Netherlands[1]. Other useful applications of them include fish sales (Fluvià, Garriga, Rigall-I-Torrent, Rodríguez-Carámbula, & Saló, 2012), after-Christmas sales (Miettinen, 2013), share repurchase (Brown & Davis, 2012), airline overbooking (Gretschko, Rasch, & Wambach, 2014), cash management (Alderson, Brown, & Lummer, 1987), tobacco sales (McAfee & McMillan, 1987), cloth sales (Crawford & Kuo, 2003), vehicle slot sales (IPART, 2007), and initial public offerings (Robinson & Robinson, 2012).

1.2. Motivation of study

It is normally assumed in the auction literature that the bid price is a continuous variable and it can take on any value in a certain range (David et al., 2007; Li & Kuo, 2011, 2013; Rothkopf & Harstad, 1994). The implication is that extremely small bid decrements may be used by the auctioneer to test the bidder's valuation of the object for sale and the auction could last for a long time.

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[1] A notable example of Dutch auction can be found in Royal FloraHolland of the Netherlands. It is the largest international flower auction house in the world, where 12.5 billion flowers and plants were sold with an annual revenue of €4.6 billion in 2016, an increase of 3.8% compared with the year of 2015 (www.royalfloraholland.com).

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While such a market mechanism might be appropriate for auctioning off a unique object (e.g., an antique), it is clearly not applicable to fast Dutch auctions where perishable goods or services are sold very quickly. For instance, it is reported that each auction at Royal FloraHolland lasts for approximately four seconds (Kambil & van Heck, 1998). Gallegati, Giulioni, Kirman, and Palestrini (2011) and Guerci, Kirman, and Moulet (2014) also observe that 15 transactions are completed per minute by using three simultaneous clocks in a fish market in Italy.

To date, only a handful of researchers have studied Dutch auctions with discrete bid levels (Li & Kuo, 2011, 2013; Yu, 1999; Yuen, Sung, & Wong, 2002) and it has been proven that the expected revenue increases with the number of bid levels set. In the auction literature, it is traditionally assumed that, as an agent of the seller, the auctioneer acts in his client's interest (Cassady, 1967). However, such an assumption can be problematic because a seller is only interested in the selling price in his auction but the auctioneer is mainly concerned with the total revenue generated from various sellers during its operating hours. While the use of more bid levels yields a higher revenue from an auction, it may not be the optimal strategy to follow in reality since the auctioneer typically conducts multiple auctions for different sellers. The longer duration causes a smaller number of transactions to be completed during the regular operating hours of an auction site and the total revenue generated might not be as high as it can be. Hence, from the auctioneer's perspective, a more practical and meaningful objective to pursue is maximization of the expected revenue per unit of time instead of per auction.

In this research, we mainly focus on the oral Dutch auctions at the for-profit auction house. We attempt to explain why the fast Dutch auction happens in practice and explore the real mechanism used by the auction house. In industry, time has been well recognized as an important constraint for the auctioneer in the open-outcry auctions where the bidding prices are called out by the auctioneer. Chipty, Cosslett, and Dunn (2015) investigate 400 auctioneers from the National Auctioneers Association, and their survey reports that, in the outcry English auctions, 92% of auctioneers have closed bidding even though they thought a higher bid was possible in order to move on other auctions in a timely fashion.

1.3. Purpose of study

The main thrust of this manuscript is to tackle a new class of discrete Dutch auction problems in which the goal is to determine the number of bid levels to be set and the asking price at each level so that the auctioneer's expected revenue per unit of time is as high as possible. To the best of our knowledge, this kind of study has not been conducted by any other researchers to date.

Another purpose of this work is to investigate the effect of information about the number of bidders on the auction outcome. While the number of bidders in an auction was often assumed to be given in publications prior to the 1980s, it has been treated as a random variable in more recent research (Isaac, Pevnitskaya, & Schnier, 2012; Levin & Ozdenoren, 2004; McAfee & McMillan, 1987). Studies comparing the outcomes between auctions with known and unknown numbers of would-be buyers remain limited in the existing literature. The present paper analyzes the differences in the auctioneer's expected revenues per unit of time in discrete Dutch auctions between two classes of models: one with a fixed number of bidders and the other with a random number of bidders. Thus, the results from this inquiry are new and should contribute to the field of mechanism design.

The remainder of this paper is organized as follows. The mathematical notation to be used and the basic assumptions to be made are described in Section 2. A basic discrete Dutch auction with a fixed number of bidders (Model I) for maximizing the auctioneer's expected revenue per unit of time is examined in Section 3. Then, Models II and III are presented as variations of Model I in which the bidders' valuations follow an exponential distribution and a truncated normal distribution, respectively. In Section 4, Models IV–VI are the probabilistic counterpart of Models I–III, where the number of bidders in the auction is a Poisson random variable. The major results from this research are discussed and a comparative study is conducted in Section 5 to highlight the trade-offs between auction revenue and duration. Finally, we discuss the significance of the paper and point out a few directions for future research in Section 6.

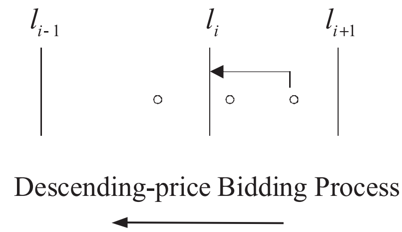

Fig. 1. Discrete Dutch auction with a selling price of $l_i$for object.

2. Preliminaries

We consider discrete Dutch auctions whose objective is to maximize the auctioneer's expected revenue per unit of time by determining the number of bid levels to be used and the asking price at each level. Under the assumption of an independent private value (IPV) setting with symmetric information, each bidder knows how much he/she values the object to be auctioned off and this valuation is neither known to other bidders nor affected by their valuations. It is also posited that all risk neutral bidders are rational to bid based on their own valuations. Given $n > 0$ bidders, it is assumed that the private valuation of bidder j, v_j, is an independent and identically distributed continuous random variable with probability density function (PDF) f and cumulative distribution function (CDF) F, $j = 1, 2, \ldots, n$.

Suppose that $m \geq 1$ bid levels $l_1, l_2, \ldots, l_m$ are to be set. If the object failing to be sold at the end of the auction has a salvage value u, then we have $0 \leq u \leq l_1 \leq l_2 \leq \cdots \leq l_m$. The auctioneer begins with an arbitrarily high asking price l_{m+1} and lowers it to each of $l_m, l_{m-1}, \ldots, l_2, l_1$ sequentially every $s > 0$ seconds, where s is termed the clock speed. The selling price is l_i if and only if $q \geq 1$ bidders' valuations are in the range $[l_i, l_{i+1})$, no one is willing to pay the higher price l_{i+1} announced previously, and the remaining $n - q$ bidders' valuations are below l_i, $i \in \{1, 2, \ldots, m\}$. In case two or more bidders' valuations fall in the aforementioned range (i.e., $q \geq 2$), the first bidder to call out "mine" or push the button is the winner. An example with $n = 3$, $q = 2$, and $n - q = 1$ is graphically illustrated in Fig. 1, where the circles indicate the bidders' valuations and the arrow points to the selling price of the object to be auctioned off.

3. Models with a fixed number of bidders

3.1. Model formulation

A discrete Dutch auction with a fixed number of bidders is considered in this section. Let $P(l_i)$ denote the probability that the object is sold at the bid level l_i, $i = 1, 2, \ldots, m$. Based on the previous discussions about Fig. 1, we have

$$P(l_i) = \sum_{q=1}^{n} \binom{n}{q} F(l_i)^{n-q} [F(l_{i+1}) - F(l_i)]^q$$