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Dual Mechanism in Electronic Retailing

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Abstract

In the past, a retailer usually chose only one market mechanism, either a posted price or an auction, for a product. However, currently some web stores sell a product at a posted price and simultaneously run auctions for the identical product. This new phenomenon has not been studied fully yet. We study a new selling mechanism, Dual Mechanism, where an online retailer combines two famous conventional mechanisms (Posted Price and Auction) together. This paper presents our initial work towards understanding of this mechanism.

Keywords: Business model, eCommerce, price discrimination

Introduction

While posted price and auction-based pricing mechanisms have typically been seen as alternatives, the simultaneous use of these mechanisms (by a single firm and for the same product) has grown with the commercialization and widespread use of the Internet. Internet-based pricing technologies give firms a fairly low-cost means to provide and to customize information about prices and related factors, such as delivery times. In some cases, the seller uses the two mechanisms jointly but only to move two separate classes of goods (e.g., in-fashion clothing vs. out-of-style clothing), which is easily explained as a case of quality-based price discrimination. Our focus of this paper is on examining a new selling mechanism, which hereafter we call the Dual Mechanism, on the current Internet: the simultaneous use of a posted pricing scheme with immediate delivery and a multi-unit auction with delivery delayed to the end of the auction. 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 to these large firms, there are many relatively small online retailers on eBay.com who offer a posted price market with immediate delivery and a simultaneous multi-unit auction.

Why would such a Dual Mechanism make sense? Since buyers have the option of purchasing at the posted price, why would any rational buyer ever bid greater in the auction, especially given the delayed delivery? Given this fact, why would the firm have any incentive to sell some units of the product through an auction at a lower price? The purpose of this paper is to explain how this Dual Mechanism affects the complex interplay that the seller faces between revenues and costs. The intuition is that when buyers have time- or delay-sensitive valuations, then the simultaneous offering of these two mechanisms can help the firm exploit heterogeneity in delay sensitivities and separate high-type and low- type buyers. Moreover, the distinctive aspect of our analysis is that we take into account the cost, specifically the inventory structure, of the seller's operations. The seller holds enough inventory to satisfy only high-type buyers, while it fulfills the demand of low-type buyers without incurring holding costs.

Since live auctions have existed for a long time, many researchers have studied the optimal strategies for participants and the efficiency of the auction system; see, for examples, Myerson (1981); Milgrom and Weber (1982); Maskin and Riley (1985); McAfee, Preston, and McMillan (1987). There are also some interesting papers comparing two market mechanisms. Wang (1993, 1998) compares auction mechanism and posted-price mechanism in a one-period model. Wang (1993) demonstrates that an auction is preferable if there were no auctioning costs. Furthermore, Kultti (1997) shows that the two market mechanisms are practically equivalent. However, these studies are unable to fully describe the characteristics of the Dual Mechanism, because most of these studies are mainly focused on pure auction markets or do not allow customers to observe the markets before entering a market (i.e., irreversible choice to enter either market).

Problem Statement and Formulation

Overview of Model and Prelimilary Results

We consider an online retailer who sells a product through a web store and manages inventory using an EOQ-type policy. We assume that customers arrive at the web store at a constant rate, d, at each period and that the customer valuations for the product are uniformly distributed between 0 and 1 (i.e., $V \sim U[0,1]$). We also assume that a customer's valuation decreases, due to the waiting time for the product, until she receives it. We model this disutility as a linear function of the customer's valuation and waiting time. Specifically, if a customer with valuation v gets the product after t periods, then the customer's utility is $v(1\text{-}wt)$ where w ($0 < w < 1$) is a constant representing delay sensitivity.

For simplicity, we assume that the lead time between order placement and order arrival is deterministic and that the customers get the product immediately after the retailer ships the product. Without loss of generality, we assume that the retailer delivers the ordered products immediately for the posted price customers, but fulfills the auction winners' delivery at the closing time of the auction. The retailer can purchase the product at unit purchasing cost, c. The inventory costs include an ordering cost, A, per order and a unit holding cost, h, per period. The retailer's objective is maximizing the expected profit per unit time by simultaneously deciding cycle length (T), posted price (p_p), and number of units for the auction (N).

Through our analysis, we have found that, under the Dual Mechanism, there exists an indifference point at each period and that the customers choose either the posted price or auction by comparing this indifference point with their valuation for the product. We omit the details of these results due to the space limit.

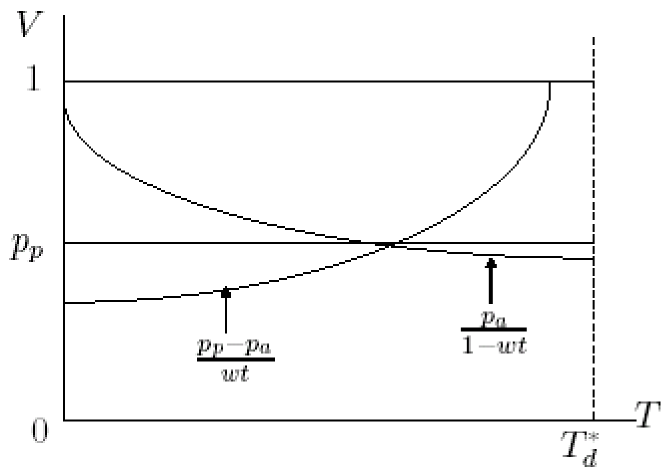


Figure 1. Description of the Dual Mechanism

Formulation of the Dual Mechanism

To formulate the retailer's profit maximization problem, we define two specific points in the cycle. Let t_x be the length of remaining periods where the indifference line (i.e., $\frac{p_p - p_a}{wt}$) and the posted price (p_p) intersect and let t_y be the length of remaining periods where the indifference line and upper limit of valuations (i.e., 1) intersect. Hence,

$$t_x = \frac{p_p - p_a}{w \cdot p_p}, \quad and \quad t_y = \frac{p_p - p_a}{w}$$

where p_a is the auction's winning price. Using these two terms, the total demand for the posted price (refer to Figure 1) can be expressed as

$$(T - t_x)d(1 - p_p) + \int_{t_y}^{t_x} d\left(1 - \frac{p_p - p_a}{wt}\right)dt.$$

And the corresponding inventory holding cost is

$$h\int_{t_x}^{T} d(1 - p_p)(T - t)dt + h\int_{t_y}^{t_x} d\left(1 - \frac{p_p - p_a}{wt}\right)(T - t)dt.$$

Therefore, the retailer's total expected profits per unit time are

$$\frac{(p_p - c)\left[(T - t_x)d(1 - p_p) + \int_{t_y}^{t_x} d\left(1 - \frac{p_p - p_a}{wt}\right)dt\right] + (p_a - c)N}{T}$$
$$- \frac{h\int_{t_x}^{T} d(1 - p_p)(T - t)dt + h\int_{t_y}^{t_x} d\left(1 - \frac{p_p - p_a}{wt}\right)(T - t)dt + A}{T}.$$

Now we derive the relationship between the number of units (N) and the auction winning price (p_a) as follows:

$$N + 1 = d\int_0^T \left(1 - \frac{p_a}{1 - wt}\right)dt - \left[\int_{t_x}^{T} d\left(1 - \frac{p_a}{1 - wt}\right)dt + \int_{t_y}^{t_x} d\left(1 - \frac{p_p - p_a}{wt}\right)dt\right].$$

The first term on the RHS of the above equation represents the total expected demand if there were no posted price market. Note that some customers of this total demand will choose the posted price due to the co-existence of the two market mechanisms, and the sum of second and third term represents the number of customers who prefer the posted price.

Simplifying the above equations gives the retailer's total profit per unit time as

$$\max_{p_p, N, T} \quad \frac{(p_p - c)d\left(T(1 - p_p) + \frac{p_p - p_a}{w}\ln[p_p]\right) + (p_a - c)N}{T}$$
$$- \frac{hd\frac{(T - t_x)^2(1 - p_p)}{2} + hd\left(\frac{(t_x - t_y)(2T - t_x - t_y)}{2} + \frac{(p_p - p_a)(t_x - t_y + T\ln[p_p])}{w}\right) + A}{T}$$

$$s.t. \qquad N = d\left(t_y + \frac{p_a \ln[p_a] - p_p \ln[p_p]}{w}\right) - 1$$

$$p_a \le p_p, \quad 0 \le p_p \le 1, \quad 0 \le p_p \le 1, \quad N > 0,$$

where $t_x = \frac{p_p - p_a}{w \cdot p_p}$ and $t_y = \frac{p_p - p_a}{w}$.

Computational Experiment and Observations

Because the characteristics of the Dual Mechanism's optimal solution are not tractable, we conduct a computational experiment and discuss some meaningful observations to extend our understanding of the Dual Mechanism. In the experiment, we vary the values of parameters (i.e., $d \in \{200, 400, 800\}$, $h \in \{0.01, 0.05, 0.1\}$, $c \in \{0.1, 0.2, 0.3\}$, $A \in \{3, 5, 10\}$, and $w \in \{0.01, 0.05, 0.1\}$), and derive optimal solutions for the three conventional selling mechanisms: Pure Posted Price (PPP), Pure Auction (PA), and Dual Mechanism. To summarize, we have total 243 cases, and 729 optimal solution sets for the experiment. From the analysis of the computational experiment, we observe the following results:

Observation 1. *The Dual Mechanism strictly dominates the PPP mechanism.*

This observation is not very surprising since the retailer can always be better off by adding the auction market to the posted price market. We note that the Dual Mechanism has two main effects compared to the PPP mechanism. The first effect is the inventory cost savings, and the second is the increased market coverage due to the auction. Therefore, the retailer is able to achieve higher profits by allocating a smaller number of units to the auction market.

Observation 2. *The Dual Mechanism does not always outperform the (PA) mechanism.*

This observation is somewhat counterintuitive because one can think that providing two choices to the customer will increase the retailer's profits. But consider the effect of the Dual Mechanism compared to the PA mechanism. The Dual Mechanism implements a price discrimination model based on the customer's waiting sensitivity. Therefore, this price discrimination can increase the retailer's profit when the loss due to the price discrimination is less than the gain. To implement this discrimination, the retailer has to keep positive stocks for the high type (delay-sensitive) customers. Now consider the case where the customers are not delay-sensitive. Then the retailer cannot gain much profit from the high type but incurs inventory holding costs. Therefore, in this case, the retailer can be strictly better off by choosing the PA mechanism when the customers are not delay-sensitive and the unit holding cost is relatively high.

Observation 3. *Under the Dual Mechanism, delay-sensitive customers pay a strictly higher price compared to the PPP mechanism. However, the Dual Mechanism increases market coverage.*

The higher price can be explained using the inventory cost-saving effect of the Dual Mechanism: the retailer can reduce the holding cost's burden; hence, she can set the posted price higher. The increased market coverage is due to the auction's lower winning price. However, this phenomenon does not extend to the PA mechanism. The explanation is that the movement from the Dual to the PPP mechanism gives the retailer inventory cost savings and increased market coverage, whereas the movement from the PA to the Dual mechanism only gives the price discrimination effect at the expense of increased inventory costs. These different benefits of the Dual mechanism result in the non-symmetric results in our observations.

In summary, these observations can explain why we now observe the Dual Mechanism on the Internet and partly explain the proliferation of the online auction on the Internet.

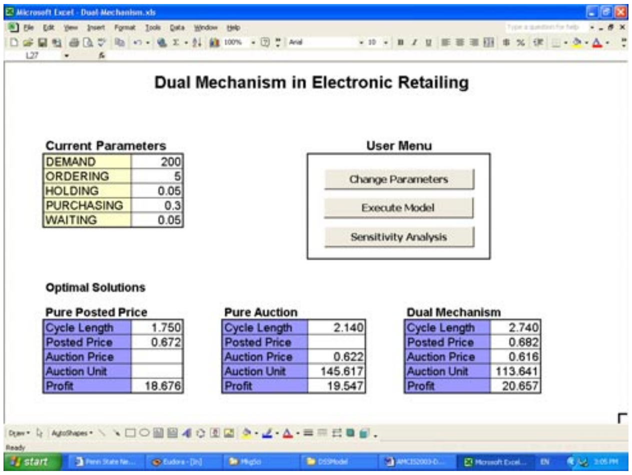
Decision Support System

We have developed a DSS model to help practitioners investigate and examine three conventional mechanisms. Our model uses Microsoft Excel for user interface and GAMS (MINOS) for problem solver, and it consists of four user interface windows: Main User Interface, Parameter Change, Sensitivity Analysis Menu, and Result of Sensitivity Analysis (Figure 2). Due to the space limit, we omit the details.

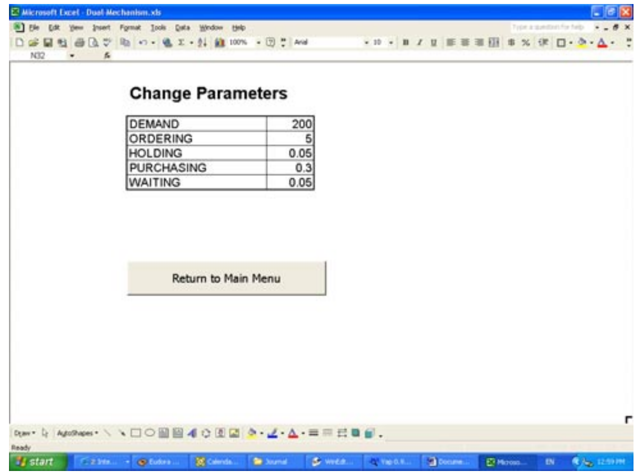
Conclusion and Future Research Direction

Recently we observe many online retailers who implement the Dual mechanism where the customers can buy the product at a fixed posted price or participate in a multi-unit auction. Since this phenomenon is relatively new, there is no clear explanation for the motivation of the retailers or of the customer's purchasing and bidding behavior. In this paper, we seek to understand this new phenomenon with deterministic customer's valuation and an EOQ-type inventory setting.

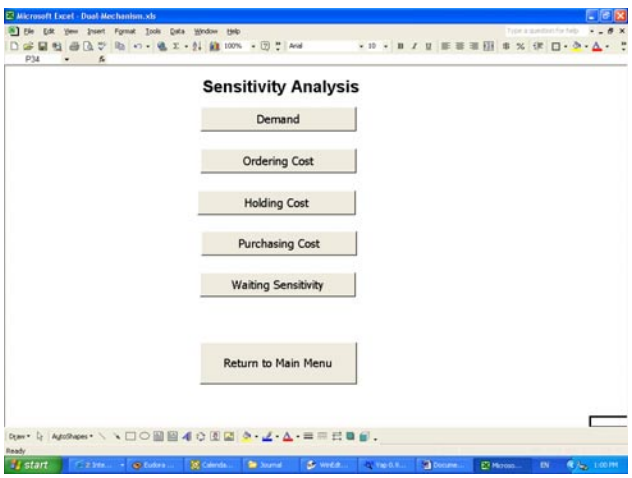
There could be several reasons for the existence of the Dual Mechanism for a product in the Internet, but we limit our discussion to the trade-off between the lower winning price at the auction market and the customer's waiting time disutility. Therefore, high-type (delay-sensitive) customers prefer the posted price, and low-type (delay-insensitive) customers prefer the auction.



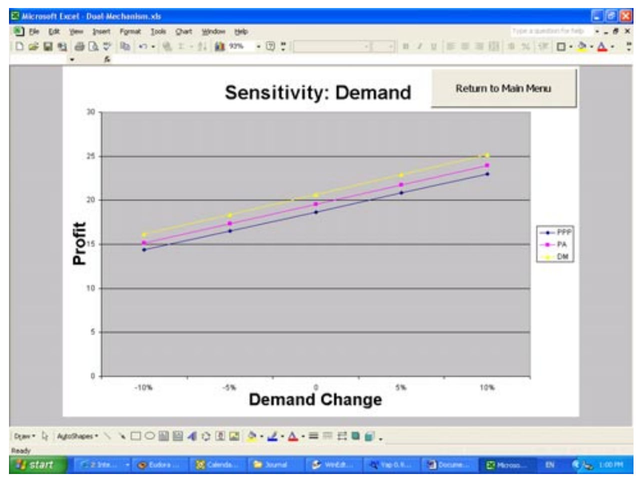
(a) Main User Interface Window



(b) Parameter Change Window



(c) Sensitivity Analysis Menu Window



(d) Output of Demand Sensitivity Analysis

Figure 2. DSS Model for Managers

Our future plans include analytical proofs of the observations from our computational experiment, generalization of the customers' valuation distribution and waiting disutility, and further investigation of the Dual Mechanism under expanded model settings.

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