Using Auction Mechanisms for Pricing Information Goods Bundles

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Extended Abstract

Overview

In this paper, we provide a sealed bid, multi-unit auction mechanism for pricing information goods bundles. With the digitization of various products and growth of the internet as a delivery system, there has been increased interest in developing methods to price information goods. The low marginal cost of production, the lack of capacity constraint on production and ease of bundling products affect the pricing and allocation strategies of firms selling information goods. Previous work on bundling information goods assumes ex-ante knowledge about either consumer valuations (or reservation prices) or their distributions. In this paper, we relax these assumptions and develop an incentive-compatible auction mechanism to determine bundle prices and allocation. Of course, when valuations or reservation prices are known ex-ante, one can solve a nonlinear optimization problem which will give a higher revenue than our incentive compatible mechanism. Conversely, even if valuations or reservation prices are unknown, one could use a fixed price strategy to price information goods bundles. We will compare our mechanism with other pricing options for information goods bundles.

1. Introduction

With the digitization of various products and growth of the internet as a delivery system, there has been increased interest in developing methods to price information goods. The emergence of the intenet as the backbone for a well-developed marketplace has spurred research in pricing of information goods. Recent research in this area includes Bakos and Brynjolsson (1999), Armstrong (1996), Hitt and Chen (2003), Chuang and Sirbu (1999) etc. In this paper, we aim to provide an incentive-compatible, non-linear programming formulation to determine the bundle prices and allocation for goods that have low marginal cost of production (e.g. information goods). The model can be used in various settings like bundling of software products, selling bundles of similar goods (e.g. music downloads, CDs, DVDs and books), selling of pay-per-view programs on cable, broadcast of movies etc. In all these settings, the marginal cost of production is very low and the sellers face a heterogeneous group of consumers whose valuation for various items is not evident.

Recent research has pointed out various situations under which pure bundling and customized bundling are better revenue maximizing alternatives than selling single units of the product. Also, bundling helps the seller address the need of a wider audience. Bakos and Brynjolfsson (1999) showed that under assumptions of zero marginal costs, and i.i.d customer valuations for goods, pure bundling is optimal for a multi-product monopolist. However, when the above assumptions are not satisfied, pure bundling need not remain the optimal strategy for the monopolist. In the presence of additional constraints like the budget constraint, pure bundling would not be optimal if the budget limit is reached for some of the consumers. Hence, although these consumers could still give a positive surplus to the seller, the exposure constraint essentially prices them out. Offering customized bundles would be better in such situations. Also, in the case where a large number of information goods are being offered for sale (CDs, music downloads, movies, books etc.), each consumer is likely to have a preference over a small subset of the items. Thus, additional constraints related to taste and the ability to evaluate the information goods also come into play. As all people may not positively value all information goods, Chuang and Sirbu (1999) show that mixed bundling is always a dominant strategy and under certain conditions, pure bundling can be inferior to pure unbundling. Using a mathematical programming formulation, Wu, Anandalingam and Chen (2002) showed that when there are non-homogeneous consumers, customized bundling might be a better strategy than pure bundling. In fact, King and Griffiths (1995) show that out over 40% of those surveyed read no more than five articles of the nearly hundred articles published in journals. This study supports the hypothesis that consumers have positive valuation for only a small group of items amongst all possible offerings.

Hitt & Chen (2003) discuss an alternative bundling mechanism for low marginal value goods where the consumer has an option to choose any subset of goods (i.e. upto a specific quantity of goods) from the entire available set. The customized bundling solution is of much lower complexity than solving pricing and allocation for preferences over the $2^N - 1$ possible bundles that a typical second degree price discrimination problem with bundling would solve. They also discuss the applicability of customized bundling to situations where customers do not have positive valuations over all goods. Hanson and Martin (1990) formulate the bundling problem as a mixed integer linear program and demonstrate computational results for small number of items (upto 21 components). Wu & Anandalingam (2002) have extended this model to solve large-sized problems.

Our work aims to combine the work of Hitt & Chen (2003) with the modeling approach of Hanson and Martin (1990) and further add incentive compatibility property to the bids by incorporating constraints to ensure bid-independence for the price paid by the consumer for the specific bundle. This paper aims to provide guidance to a firm selling a large number of homogeneous goods by using a multi-unit auction mechanism to determine optimal bundle size for each buyer along with associated price. In modeling papers like Hanson & Martin (1990) and Wu & Anadalingam (2002), it is explicitly assumed that the seller has complete knowledge about the value that the buyers associate with elements of the bundle. Similarly, other research work related to bundling typically assumes that the buyer valuation distribution is known. *This is a very strong as well as invalid assumption.* As the seller is trying to maximize her own surplus based on the prices quoted by the bidders, the bidders have an incentive to shade their bids as they are assured of being allocated some bundle irrespective of the price that they quote (assuming the price is above the marginal cost of production/ reserve price for the seller).

Our paper relaxes the assumption about knowledge of true bidder values and proposes a mechanism to help the seller estimate the true valuations for the items in the bundle. Bid-independence property is specifically incorporated into the NLP formulation by adding constraints, so that the mechanism is incentive compatible. The bidders are assumed to have (weakly) diminishing marginal values. We note that pure bundling is an extreme example of customized bundling, and thus is treated as a special case in our model. Although our model is designed under assumptions of diminishing marginal values and homogeneous goods, the non-linear programming model can accommodate not only any kind of demand distribution or consumer valuation functions, but also the marginal bundle cost of a bundle and the menu cost, which may occur in offering multiple bundles. Moreover, since the variables in our model grow in polynomial space with respect to the number of goods, our model can be solved for a very large number of information goods. Given any demand curve and cost structure, our model can determine how many bundles the information goods provider should offer, and the price it should charge for each bundle. A related paper by Goldberg, Hartline and Wright (2001) examines a class of single round, sealed bid auctions for items in unlimited supply and shows that any deterministic bid-independence auction is truthful.

We introduce our model formulation in section 2, the NLP formulation in section 3 and discuss work-in-progress and research direction in section 4.

2. Problem Formulation

In this section, we formulate the incentive compatible, optimal bundling and pricing problem for an information goods seller. The seller's problem is to find the bundle sizes to be offered as well as a price for each offering so as to maximize its profit subject to a set of consumer participation and incentive constraints. As the mechanism is incentive-compatible, the buyer will give its true prices for various bundles i.e. give the seller its demand curve. Similar to the assumption in Stigler (1963), the customer demand information is given by a vector of reservation prices for the bundles of various sizes.

The price is only determined by the size of the bundle and not its contents. Thus, the seller will offer each customer a bundle of items and the customer can specifically decide what would determine the exact contents of the bundle (e.g. if we take the example of music download, the allocation to a customer would be a bundle of say 5 songs at a price of $4 and the buyer can then decide which songs to download). The number of bundles for sale will be limited as there can be overhead costs associated with providing bundles as well as cognitive costs to consumers if a very large set is offered. The non-linear programming model that we develop could include these costs.

We will model the problem of optimizing the customized bundles for information goods and pricing them as a nonlinear integer mathematical programming problem. Given below are the definitions of all the parameters and variables used in this model.

Decision Variables

$X_{ij} \in \{0,1\}$ – bidder ‘i’ determines the price of a bundle of size’j’
P_j – price of bundle of size ‘j’
$Y_{ij} \in \{0,1\}$ – 1, if bidder ‘i’ gets bundle of size ‘j’
0, otherwise

Given Data

b_{ij} – bid of bidder ‘i’ for bundle of size ‘j’
m.c. – marginal cost of production

Assumptions for the model are:

- n-1 actual bidders, 1 dummy bidder (with bids equaling marginal cost of production for the unit)
- m good bundles – goods can be bundled upto a maximum size of ‘m’
- Bidder valuations depend only on the number of goods in the bundle and not specific items in the bundle
- The marginal value for every bidder is specified; optimization problem uses as input the cumulative bids for each bidder

3. Non-linear Programming formulation

The objective function of the seller is to maximize total profits, which is the summation of revenues obtained from the buyers minus the marginal cost of production. Also, the price that we seek is a uniform price i.e. a bundle of a specific size will be allocated at the same price to all selected bidders. The formulation is as follows:

Max $\sum_{j=1}^{m} P_j (\sum_{i=1}^{n} Y_{ij}) - (m.c.)\sum_{j=1}^{m} j(\sum_{i=1}^{n} Y_{ij})$

s.t. $\sum_{i=1}^{n} X_{ij} = 1, \forall j$ - only one bidder (either real or dummy) determines the price of a bundle

$\sum_{j=1}^{m} Y_{ij} \leq 1, \forall i = 1,.., n-1$ - each bidder gets only one bundle

$P_j X_{ij} \leq b_{ij}, \forall i, j$ - price of the bundle cannot be greater than the bidder’s bid that determines it

$P_j Y_{ij} \leq b_{ij}, \forall i, j$ - Individual rationality constraint

$X_{ij} Y_{ij} = 0, \forall i, j$ - the bidder who determines price will not be allocated the bundle of that size

$Y_{nj} = 0, \forall j$ - the dummy bidder will not be allocated any bundle

$P_j \geq P_{j-1}, j = 2,.., m$ - price of a larger bundle should be more than a smaller one

4. Work-in-progress

Our research aims to run simulations to compare the revenue and resource allocation from the solution to the above NLP formulation with the following:

- Solution obtained from implementing a suitable fixed-price scheme (i.e. each unit is priced at an optimum constant price), assuming that the true valuations are known ex-ante to the fixed price mechanism
- Solution from a uniform pricing scheme (similar to the NLP formulation above but with the assumption that the declared valuations for the items are the true values)
- A Groves-Clark implementation and related revenues and allocation.

The simulation runs will help us understand the "cost of truth revelation" incurred by the auctioneer, when the number of bidders and the number of items being auctioned-off vary.

5. References

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