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Designing a retail store network with strategic pricing in a competitive environment

Yue Zhang *

College of Business and Innovation, University of Toledo, 2801 W. Bancroft Street, Toledo, OH 43606, USA

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ABSTRACT

This paper presents a location and pricing model for a retailer that sells a homogeneous product to maximize profit in a competitive environment. Specifically, the retailer is to locate a given number of stores and simultaneously to determine the mill price charged at each open store. We assume that mill price and travel cost are two main utility factors considered by customers, and adopt the multinomial logit model to express the flows of customers traveling to stores. The problem is formulated as a mixed integer nonlinear program. We develop a solution framework composed of two phases (location and pricing) to solve the problem. Given a set of open stores, three pricing heuristics are used to determine the optimal price at each open store. Three location heuristics are proposed to find the best set of open stores. Computational experiments suggest us to use a path-following approach provided in the literature for pricing and a tabu search procedure for location. We finally investigate an illustrative example and derive a number of managerial insights regarding location and pricing strategies.

1. Introduction

This paper studies the problem of designing a store network with strategic pricing for a retailer that sells a homogeneous product in a competitive environment. The location and pricing decisions at each store are main determinants of this problem, and they are assumed to be made simultaneously. Traditionally in operations management, people consider that location and pricing decisions are made separately, as locations are long-term decisions while prices can change over time. However, Hanjoul et al. (1990) discussed the shortcomings of this view and indicated that separating location and price decisions leads to suboptimality. There is rich literature in operations research and economics that have found that a joint location and pricing scheme is helpful to maximize profit. For example, Aboolian et al. (2008) further pointed out that post-locational price flexibility is often limited in practice and argued that “a company may not need to determine the exact prices they will charge for their products at the time the location decisions are being made; however, the determination of the range of prices they intend to use relative to the competition should not be separated from the location decision.” This exactly presents the significance for strategic pricing that we intend to focus on in this paper, i.e., how much to charge strategically at each store depending on the environment when a store network is designed.

The policy that different prices are charged at different stores or facilities is called *mill pricing*. This policy is used in many industries in real life. A good example of mill pricing is in the fast food industry. Based on the pricing information of 79 outlets (38 Burger Kings and 41 McDonald's), Thomadsen (2007) found that the prices of the signature sandwich are different at different stores. Burger King Whoppers meals can be priced from $3.19 to $3.69, with a mean of $3.26 and a standard deviation of $0.11, while the price of McDonald's Big Mac meals ranges from $2.99 to $4.09, with a mean of $3.46 and a standard deviation of $0.27.

Chan et al. (2007) presented another example in the competitive environment. They examined the prices of 98 UL gasoline at various retail chains in Singapore. They observed that the average price of 98 UL gasoline at Singapore Petroleum Company is $1.14 per liter, which is approximately $0.05 lower than at other retail chains; the standard deviation of price of gasoline is $0.03 for most retail chains, which is much smaller than that observed in U.S. markets. Their empirical analysis also demonstrated that the local presence of other stations belonging to the same chain has an increasing effect on price at the focal station, whereas the number of stations belonging to competing chains has a decreasing effect on price at the focal station.

In contrast, the policy that an identical price is charged at all stores or facilities is called *uniform pricing*. This is also a widely used policy in real life. For example, postage stamps are typically sold at the same price across all postage offices. In addition, there

* Tel.: +1 419 530 2380.
E-mail address: yue.zhang@utoledo.edu

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are other pricing policies used in different situations or industries, including *spatial discriminatory pricing*, *uniform delivered pricing*, and *zone pricing*.

We focus on mill pricing and uniform pricing in the paper. In terms of modeling, uniform pricing can be considered as a special case of the former. Therefore, our model below is mainly developed based on mill pricing. In practice, a firm could choose whichever policy is preferred. Specifically, we consider that a retailer (referred to as the focal retailer) is to locate a given number of stores on a network to sell a homogeneous product and simultaneously to determine the mill price charged at each store to maximize profit. On the network, there are existing stores that belong to another retailer and sell the same product. The locations and prices of these existing stores are given and fixed. The potential demand over the network is assumed to be given. We assume that a customer is free to choose where to purchase the product, and that mill price and travel cost are two main utility factors that would affect the decision. To capture the impact of other factors and randomness, we express the probability of a customer who patronizes a store of either the focal or the other retailer based on a multinomial logit (MNL) model (McFadden, 1974). That is, the probability of a customer choosing a certain store is proportional to the utility of patronizing the store.

In particular, there are two key issues that we intend to model and investigate in this location and pricing problem. One is the trade-off between mill price and travel cost. Customers may prefer to travel farther to purchase a product with a lower price. The other issue is the competition between the focal retailer and the other ones. In this circumstance, we investigate how to locate the stores and charge the product strategically so as to maximize profit. Note, however, that the competition here is *static*, and there is no reaction or gaming, which would be a natural extension.

The main contribution of this research lies in three perspectives. First, we present a new spatial location and pricing model on a network, which incorporates mill pricing, competition, and the MNL model. Second, we propose and compare several alternative solution methods to solve the problem. Finally, by investigating an illustrative example and randomly generated problem instances, we discuss several interesting findings and managerial insights regarding location and pricing strategies. For instance, our analysis shows the superiority of the mill pricing policy over the uniform pricing policy. The analysis also supports the empirical observations in the literature that the local presence of stores belonging to competing retail chains has a decreasing effect on price, while that belonging to the same retail chain has an increasing effect. Moreover, our results suggest that the intensity of competition and customers’ sensitivity to the price and travel cost have a significant impact on the pricing strategy.

The remainder of the paper is organized as follows. The next section provides a brief literature review. Section 3 describes the problem and formulates it as an optimization model. The solution methodology is described in Section 4. Section 5 presents computational results. An illustrative example is studied in Section 6. The final section concludes the paper.

2. Literature review

There are extensive studies about facility location and pricing problems in operations research and economics. Most of the studies can be classified into two categories: (1) *monopoly* environment, there is only a single firm in a geographic space to sell a product as a monopolist; and (2) *competitive* environment, there exist several different firms that sell homogeneous or substitute products in a geographic space.

In the monopoly environment, if one assumes that a central decision-maker assigns customers to open facilities, we call it a *centralized* model. For instance, Erlenkotter (1977) developed a location and spatial discriminatory pricing model to maximize net social benefits subject to ensuring sufficient revenues to cover costs. Hanjoul et al. (1990) compared uniform pricing, uniform delivered pricing, and spatial discriminatory pricing for plants in order to maximize profit. Hansen et al. (1997) used the zone pricing policy to maximize profit. All of these problems are based on a network, and they are formulated as mathematical programs.

In contrast to a centralized model, a *user-choice* model allows customers to choose a facility instead of being assigned. For example, customers are assumed to patronize the closest open facility or the one with the lowest total cost which is composed of travel cost and mill price (Chu and Lu, 1998; Tan, 2001; Dasci and Laporte, 2004). They often considered the problems on a one dimension line or a plane, rather than on a network.

In the competitive environment, most of the location and pricing problems are formulated as user-choice models in operations research and economics, due to the nature of competition.

One category of these studies focuses only on optimizing decisions of one firm, given the other(s) fixed. Several studies do not address pricing decisions (Hakimi, 1983; ReVelle, 1986; Hua et al., 2011), which present models of locating a fixed number of new facilities on a network, given that there already exist a number of facilities. Price is either not considered or set exogenously in these models. Other studies incorporate an uniform pricing decision in the location models for an entering firm to maximize the profit (Serra and ReVelle, 1999; Aboolian et al., 2008; Plastria and Vanhaverbeke, 2009). Dobson and Karmarkar (1987), in contrast, addressed the leader's problem. They attempted to find a set of facilities to maximize the leader's profit subject to stability, which means that the follower cannot successfully open any new facility economically viable. In particular, all of these studies assume that customers patronize the closest facility or the one with the lowest total cost, and the models are formulated as mathematical programs.

Another category of studies considers two or more decision makers, i.e., a game-theoretic framework is constructed. Depending on whether they make decisions simultaneously or sequentially, a model can be formulated as a *Nash* game or a *Stackelberg* game, respectively. Perhaps the earliest influential study is by Hotelling (1929), who introduced the notion of spatial competition in a duopoly situation. He formulated the problem as a two-stage Nash game, where two sellers choose their locations in the first stage and compete on prices in the second stage. Many studies extended Hotelling's problem (Lederer and Hurter, 1986; Lederer and Thisse, 1990), assuming that both sellers locate first and then set discriminatory prices. Perez et al. (2004) studied the price competition only, but for any number of competitors in a general space in opposition to the traditional case of a linear market with continuously distributed demand. A number of location models on competition are also developed in the framework of Stackelberg game (Sasaki and Fukushima, 2001; Dasci and Laporte, 2005; Fischer, 2002; Sasaki et al., 2014). A lot of these Nash or Stackelberg competition models were developed on a one-dimensional line and considered only one location for each decision maker.

Most of the location and pricing studies above with user-choice models assume that customers patronize the closest store or the one with the lowest total cost (Serra and ReVelle, 1999; Aboolian et al., 2008; Plastria and Vanhaverbeke, 2009; Hua et al., 2011). This assumption often called *deterministic-choice* requires a fully informed and rational set of customers and that no other factors have an impact on customers' decision. Instead, most empirical studies commonly use the so-called *probabilistic-choice* models. They assume that a customer may patronize any store with a