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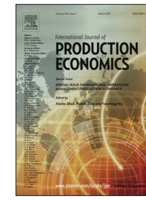

Pricing and shelf space decisions with non-symmetric market demand

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ABSTRACT

We discuss a pricing and shelf space size decision problem in a single retailer-two manufacturer supply chain where products from two different manufacturers have non-symmetric market demand functions. The retailer decides on the size of the available shelf space and the retail price for each product, while the manufacturers determine the wholesale prices for their own products. The linear demand function by Shubik and Levitan (1980) is extended to incorporate the non-symmetric market potential, production costs, and cross-price sensitivity. Mathematical models are developed to determine the optimal shelf space and retail and wholesale price, and to analyze how differences in the market potential, production cost and cross-price sensitivity of the products affect the optimal solutions. The study results show that a firm can adopt a mixed strategy of using the influence of the market potential and cross-price sensitivity simultaneously to achieve a pre-specified profit. We also show that a manufacturer can use a product differentiation strategy to offset the impact caused by an increase in production cost. Moreover, shelf space management should act in accordance with any change in the production cost of the products in the same category. We also find that the retailer can control the influence of a product's market potential and production cost on the total demand and retail prices via the shelf space cost management. Our model is the first to illustrate the interaction effect of non-symmetric market potential, production costs, and cross-price sensitivity.

1. Introduction

In retailing, the shelf space allocation problem is very important and has been studied for years. Corstjens and Doyle (1981,1983) provided a model to address the problem of how to allocate products given limited shelf space. Martin-Herran et al. (2009) extended the model provided by Corstjens and Doyle (1981,1983) to explore the influence of limited shelf space on manufacturer competition and the equilibrium space allocated to each product. Bultez and Naert (1988) and Bultez et al. (1989) provided a method for optimizing shelf space allocation for different products on a given shelf space. Their model was based on a market-share attraction model, which made it easier to estimate in practice. There are numerous marketing and supply chain management studies focused on the single shelf-space-constrained retailer shelf allocation problem (Balakrishnan et al., 2004; Chen et al., 2011; Kurtulus and Toktay, 2011; Wang and Gerchak, 2001; Urban, 1998; Yang and Chen, 1999). The results have provided useful insights for management to deal with shelf space allocation problems for a single retailer with limited display space. For the purpose of modeling simplicity, it has been assumed in previous studies using the linear demand function to help make decisions about retail shelf space, that the two competing products (i.e., products from the different manufacturers) have the same market potential, unit production cost, and cross-price sensitivity parameters (Choi, 1991; Kurtulus and Toktay, 2011). Under the symmetric characteristics described above, the previous studies have shown that the two competitive manufacturers would set the same wholesale price, the retailer would set the same retail price for the two products, and the products would share the retailer's shelf space equally. However, in the real world, this is not a common practice. There will be differences in the characteristics of two competing products when they are from different manufacturers. The products could thus have different wholesale prices, different retail prices, and be allotted different amounts of shelf space.

In this study, we consider a pricing and shelf space size decision problem for a single retailer-two manufacturer supply chain where the products from the two manufacturers have non-symmetric market potentials, unit production costs and cross-price sensitivity parameters. The retailer decides on the size of his shelf space and the retail price for each product, while each manufacturer decides on his wholesale price. To deal with the problem, the linear demand function used in Shubik and Levitan (1980) is extended to incorporate the non-symmetric characteristics described above. Shubik and Levitan's demand function has been used to reflect the

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effect of price competition between two products in a store in previous studies for years (Balakrishnan et al., 2003; Choi, 1991; Hwang et al., 2005; Kurtulus and Toktay, 2011; Piramuthu and Zhou, 2013; McGuire and Staelin, 1983; Vives, 2000; Zhou et al., 2003).

The rest of this paper is structured as follows. In Section 2, we discuss the development of the model and how it is used to determine the optimal solutions and profits for the channel members. The results are analyzed and numerical examples are provided in Section 3. Some conclusions are given in Section 4.

2. Model development

Consider a supply chain model with one shelf-space-constrained retailer and two manufacturers: manufacturer A and manufacturer B. Both manufacturers produce products in a given product category. The products from manufacturer A and manufacturer B are denoted as product A and product B, respectively. Both manufacturers sell their products through the retailer. The unit production costs of product A and product B are c_A and c_B, respectively. The retailer determines the amount of available shelf space, and orders products from the manufacturers to fill this shelf space. Let S denote the shelf space, indicating the number of units of product that can be stored on the shelf. It is assumed that the retailer stores all of his inventory on the shelf space, and that the quantity of each product ordered equals the demand for that product. Let q_A denote the demand for product A and q_B denote the demand for product B. We thus know that $q_A+q_B \le S$. The demand for each product can be determined by the following linear demand function:

$$q_A = a - p_A + \theta_A(p_B - p_A), \tag{1}$$

$$q_B = b - p_B + \theta_B(p_A - p_B), \tag{2}$$

where p_A is the retail price of product A; and p_B is the retail price of product B; θ_A and θ_B are the cross-price sensitivity parameters for product A and product B, respectively.

Thus, $\theta_A, \theta_B \in [0,1]$. Non-symmetric cross-price sensitivity parameters are introduced to allow us to demonstrate the phenomenon when the degree of product substitution is not the same for both products. a and b are the market potentials for the product A and the product B, respectively. The market potentials also represent the net consumer preferences for the products without the influence of the price. The symmetric linear demand system introduced by Shubik and Levitan (1980) widely used in the marketing and economics literature (Choi, 1991; Kurtulus and Toktay, 2011; McGuire and Staelin, 1983; Vives, 2000), is adopted and extended for incorporating the non-symmetric characteristics here.

The problem detailed in this study can be regarded as a three-stage decision problem. We assume that the retailer is the sole leader of the supply chain. The retailer first decides on the amount of shelf space to be allocated for a given product category, and then gives information to the manufacturers. Two manufactures then compete against each other to offer the best wholesale price. In essence, they play a simultaneous-move Nash game to determine the wholesale prices. Finally, given these wholesale prices, the retailer decides on the retail prices for both manufacturers' products. This problem is solved by backward induction as discussed in the following sections.

2.1. Retail price decisions

Let w_A denote the wholesale price of product A, and w_B denote the wholesale price of product B. In this stage, given the shelf space S and wholesale prices, the retailer decides on the retail prices for the two manufacturers' products in order to maximize his profit. The retailer's net profit function is

$$\Pi_n = (p_A - w_A)q_A + (p_B - w_B)q_B. \tag{3}$$

Retail pricing decisions are made, subject to $q_A+q_B \le S$. The retailer thus faces a constrained maximization problem with a nonlinear objective function. The optimal retail prices are found and shown in Lemma 1 by satisfying the Karush–Kuhn–Tucker (KKT) conditions. The proof for Lemma 1 is shown in Appendix A. Similar approaches have been used in previous marketing and logistics studies (Kurtulus and Toktay, 2011; Rajagopalan and Xia, 2012).

Lemma 1. *Given S, w_A and w_B, the optimal retail prices p_A^* and p_B^* are as follows:*

a. If $S > S_1$,

$$p_A^* = \frac{2a(1+\theta_B)+b(\theta_A+\theta_B)+w_AE_1+w_BE_3}{E_5}, \tag{4}$$

$$p_B^* = \frac{a(\theta_A+\theta_B)+2b(1+\theta_A)+w_AE_2+w_BE_4}{E_5}. \tag{5}$$

b. If $S \le S_1$,

$$p_A^* = \frac{a(3+\theta_A+3\theta_B)+b(1+3\theta_A+\theta_B)+S\times F_1+w_AF_3+w_BF_5}{4(1+\theta_A+\theta_B)}, \tag{6}$$

$$p_B^* = \frac{a(1+3\theta_B+\theta_A)+b(3+\theta_B+3\theta_A)+S\times F_2+w_AF_4+w_BF_6}{4(1+\theta_A+\theta_B)}. \tag{7}$$

The value of S_1 can be found in Appendix A. The auxiliary expressions, E_1 to E_5 and F_1 to F_6, can be found in Appendix D.

Proof. (Please see Appendix A). □

2.2. Wholesale price decisions

In the second stage, each manufacturer decides on the wholesale price of the product that maximizes profit for the given shelf space S. The profit functions for the manufactures are as follows:

$$\Pi_A = (w_A - c_A)q_A, \tag{8}$$

$$\Pi_B = (w_B - c_B)q_B. \tag{9}$$

The optimal wholesale prices are determined in Lemma 2, and the proof of Lemma 2 is shown in Appendix B.

Lemma 2. *Given S, the optimal wholesale price w_A^* and w_B^* can be determined as follows:*

a. If $S > S_2$,

$$w_A^* = \frac{a(1+\theta_B)G_1+bG_3-8c_AG_5-2c_BG_7}{G_9}, \tag{10}$$

$$w_B^* = \frac{aG_2+b(1+\theta_A)G_4-2c_AG_6-8c_BG_8}{G_9}. \tag{11}$$

b. If $S < S_3$,

$$w_A^* = \frac{1}{3}\left[2c_A+c_B+\frac{a-b+S(6+\theta_A-\theta_B)}{1+\theta_A+\theta_B}\right], \tag{12}$$

$$w_B^* = \frac{1}{3}\left[c_A+2c_B+\frac{b-a+S(6-\theta_A+\theta_B)}{1+\theta_A+\theta_B}\right]. \tag{13}$$