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Pricing and retail service decisions in fuzzy uncertainty environments

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ABSTRACT

This paper studies the pricing and retail service decisions of a product in a supply chain with one manufacturer and two retailers. It is assumed that the supply chain is operated in fuzzy uncertainty environments. The fuzziness is associated with the customer demands, manufacturing costs and service cost coefficients. Three different game structures are considered, i.e., Manufacturer-leader Stackelberg, Retailer-leader Stackelberg, and Vertical Nash. Expected value models are developed to determine the optimal pricing and retail service strategies. The corresponding analytical equilibrium solutions are obtained by solving the models. Finally, numerical examples are presented to illustrate the effectiveness of the theoretical results, and to gain various marketing strategies employed under different situations.

1. Introduction

With the current dynamic and competitive environment, the market must compete with more complicated strategies than simply lowering the product's price, because the consumers' perception of value and their purchase decisions are influenced not exclusively by the product's selling price, but also the amount of service that accompanies it. And service can help the customers obtain maximum value from their purchases [5]. Here, service is taken to broadly represent all forms of demand-enhancing effort, including customer service before and after the sale, product advertising, on-time product delivery and product placement, and the overall quality of the shopping experience.

Early research focusing on attributes such as product quality and service can be found in the economics literature, e.g., Spence [15], Dixit [3]. In marketing literature, Perry and Porter [14] focused on a type of service that has a positive externality effect across the retailers. Yan and Pei [22] considered retail services and firm profit in a dual-channel market, and suggested that the improved retail services effectively improve the supply chain performance in a competitive market. Lu et al. [12] studied three possible supply chain scenarios under manufacturer service and retail price, and obtained the results and the modeling approach which are useful references for managerial decisions and administrations. Lederer and Li [10] considered a more general problem by considering multiple classes of customers with general service time that is class-specific. Bernstein and Federgruen [2] developed a stochastic general equilibrium inventory model for an oligopoly with price and service competition. Ho and Zheng [7] considered a situation in which two competing service providers compete in terms of guaranteed delivery time and customer service level. The literature mentioned above studied the service decision with deterministic or random demand, whereas did not consider the fuzzy uncertainty of the supply chain.

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In order to make supply chain management more effective, the fuzzy uncertainty that happens in the real world cannot be neglected. For example, it is difficult to provide exact estimates of the manufacturing cost (e.g. procurement costs may be volatility), the customer demand (e.g. due to the innovation of products and market turbulence), the product supply (e.g. due to the weather conditions) and so on. However, the probability distribution may not be available in practice or may be difficult to estimate from limited data points. Under these scenarios, the fuzzy theory provides a reasonable way to deal with the possibility and linguistic expressions. The fuzzy theory provided by Zadeh [23] is an appropriate modeling tool when uncertain parameters cannot be described in stochastic distributions. There have been many researchers who adopted fuzzy theory to depict uncertainty in supply chains. They mainly focus on coordination problem [20,21], inventory problem [4,6,17], supplier selection problem [1,8], contract problem [9,19], pricing problem [27,18]. We review the literature on pricing decision in fuzzy uncertainty environments as follows. Zhou et al. [27] focused on the pricing problem of a single product with fuzzy customer demand. Wei and Zhao [18] considered the optimal pricing decision problem of a fuzzy closed-loop supply chain with retail competition. Lin and Chang [11] presented a method for order selection and pricing of manufacturer using a fuzzy approach. Zhao et al. [25,26] analyzed the pricing problem of substitutable products in a fuzzy supply chain. Zhao et al. [24] considered the optimal pricing and service decisions in a supply chain with two competing manufacturers and one common retailer. However, all of the above literature except [24] did not consider the service decision problem in fuzzy uncertainty environments.

As far as we know, no research has considered the pricing and retail service decision problem in a two-echelon supply chain as used in this paper. Our research is most related to that of [24]. The major differences between this research and the study of [24] are as follows: (1) This research considers a supply chain where one manufacturer produces a product and sells it to two retailers who are from two different areas with different economic development levels. However, Zhao et al. [24] considered a supply chain with two competing manufacturers who produce two substitutable products and sell them to one common retailer, respectively. (2) In this research, the retail service levels provided to the consumers are made by the two retailers. However, in [24], the service levels provided to the consumers are directly made by the two competitive manufacturers. (3) The manufacturer need decide the wholesale prices and the two retailers need decide the retail prices and service levels in this study, however, the two competing manufacturer need decide the wholesale prices and service levels and the common retailer only need decide the retail prices in [24].

In this paper, specifically, we consider a two-echelon supply chain where a monopolistic manufacturer sells a product through two retailers. The manufacturing cost, the customer demand and the retailer's service cost coefficients are characterized as fuzzy variables. The manufacturer needs to decide their wholesale price, and the two retailers need to make their retail price decisions and service level decisions. Our paper also focuses on the market power structures between the channel members. Three decentralized decision models are established, i.e., Manufacturer-leader Stackelberg (MS) game model, Retailer-leader Stackelberg (RS) game model and Vertical Nash (VN) game model. We assume that the two retailers have equal market power, and they engage in Bertrand competition. The Manufacturer-leader Stackelberg game scenario represents a market, in which there is a larger manufacturer and two relatively smaller retailers, and the market is controlled by the manufacturer who plays the role of Stackelberg-leader with respect to the two retailers. The Retailer-leader Stackelberg game scenario arises in a market where the two retailers' sizes are larger compared to the manufacturer's, and the manufacturer acts as the follower. If neither the manufacturer nor the retailers possess a larger bargaining power in negotiations, the supply chain interaction then follows a Vertical Nash game. Our main interest is to investigate how the monopolistic manufacturer makes his wholesale pricing decisions, and how the two retailers make their retail pricing decisions and retail service levels decisions when facing fuzzy uncertainty environments.

The rest of this paper is organized as follows. Section 2 briefly introduces the notations and the problem formulation. Section 3 gives and analyzes the three decentralized decision models. In Section 4, numerical examples are presented to illustrate the effectiveness of the theoretical results, and to compare the analytical equilibrium solutions for prices, services, and the maximal expected demands and profits under three scenarios. Section 5 summarizes our results and presents several extensions for future research.

2. Problem description

In our two-echelon supply chain structure, there are one monopolistic manufacturer and two retailers. The manufacturer produces a product with a manufacturing cost c, and wholesales it to two retailers (indexed by $1,2$) with wholesale prices w_1 and w_2, respectively. We assume the two retailers are from two different areas with different economic development levels, so the manufacturer adopts the differential wholesale prices. The retailer i sells the product to the end consumers with retail price $p_i (i = 1,2)$ and provides services directly to the consumers. We assume all activity occurs within a single period. Moreover, the manufacturer and the two retailers have perfect information of the demands and the cost structures of other channel members.

Consumer demand for the product is sensitive to two factors: retail prices and retail service levels. In defining the demand function, we follow the approach by McGuire and Staelin [13]. The demand function is decreasing in its own price, but increasing in the opponent's price. Moreover, similar to [16,12], the demand for a product is increasing in its own service level and decreasing in the opponent's service level. The customer demand faced by retailer i can be described as

$$D_i(p_1,p_2,s_1,s_2) = \alpha_i - \beta_p p_i + \gamma_p p_j + \beta_s s_i - \gamma_s s_j, \quad i = 1,2,\ j = 3-i, \tag{1}$$