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The coordinating contracts for a fuzzy supply chain with effort and price dependent demand

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ABSTRACT

This paper investigates the coordination of a two-echelon supply chain with fuzzy demand that is dependent on both retail price and sales effort. In contrast with the centralized and decentralized decision models, two coordinating models based on symmetric information and asymmetric information about retailer's scale parameter are developed by game theory, and the corresponding analytical solutions are obtained. Theoretical analysis and numerical examples yield the maximal supply chain profits in two coordination situations are equal to that in the centralized situation and greater than that in the decentralized situation. Furthermore, under asymmetric information contract, the maximal expected profit obtained by the low-scale-level retailer is higher than that under symmetric information contract.

1. Introduction

The supply chain coordination has gained considerable attention lately from both practitioners and researchers. With supply chain coordination, the supplier offers a set of appropriate contract parameters to the retailer such that the retailer's self-profit maximizing objective when making decisions is aligned with the objective of the entire supply chain. Without the coordination, double marginalization [1] exists in a supply chain system because there are two profit margins from the up-stream and down-stream supply chain member, respectively and neither firm considers the entire supply chain profit when making a decision. A properly designed coordination contract can completely eliminate the problem of double marginalization [2]. Many contracts have been presented to improve the supply chain performance, such as buyback contracts, quantity discounts, quantity flexibility agreements and so on [3–8]. Tsay et al. [9], Cachon [10] and Yano and Gilbert [11] provided extensive reviews of coordinating contracts for decentralized supply chains.

As retail pricing is an important vehicle to enhance supply chain revenue, some works have been done that study channel coordination with stochastic and price dependent demand. Apart from the retail price, in most situations, retailer sales effort is also important in influencing demand. A retailer can spur a product's demand by merchandising, commercial advertising, providing attractive shelf space, and guiding consumer purchases with sales personnel, etc. In order to coordinate the supply chain when the sales effort influences the market demand, Taylor [12] designed a returns policy with channel rebates and achieved a win–win outcome, but the retail price was exogenous. He et al. [2] extended Taylor's works and investigated the issue of channel coordination for a supply chain facing stochastic demand that is sensitive to both sales effort and retail price. The foundation of the above-mentioned papers was the manufacturer and the retailer had complete information on each other's operations.

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In many scenarios, one party holds private information and the other party makes decisions with limited available information. There are some papers on the coordination problem of a supply chain with asymmetric information, for instance, Corbett et al. [13] studied the design of supply contracts in the presence of asymmetric information, Lau and Lau [14] and Lau et al. [15] modeled a manufacturer and a retailer in a supply chain as a noncooperative game with symmetric and asymmetric information where the market demand was unknown to both manufacturer and retailer and was a function of price only.

In the real world, sometimes probability distribution of market demand may not be available to the decision maker, due, at least in part, to lack of historical data. In this situation, the uncertainty parameters are able to be approximately estimated by managers' judgements, intuitions and experience, and can be characterized as fuzzy variables [16]. The fuzzy theory provided by Zadeh [17] can be an alternative approach to deal with this kind of uncertainty. There have been a few research studies in the area of supply chain modeling with fuzzy demand [18–24]. Wong and Lai [25] provided extensive reviews for the applications of the fuzzy set theory technique in production and operations management. Zhao et al. [26] analyzed the pricing problem of substitutable products with fuzzy manufacturing costs and fuzzy demands. Wei and Zhao [27] and Wei et al. [28] considered pricing decisions in a fuzzy closed-loop supply chain. Wei and Zhao [29] explored the decisions of reverse channel choice in a fuzzy closed-loop supply chain. However, in fuzzy environment, the supply chain coordination problem under asymmetric information has not been considered.

In this paper, we consider a two-echelon supply chain and mainly focus on the fuzziness aspect of effort and price dependent demand. The decision models are developed to study the coordination problem under symmetric and asymmetric information about retailer's scale parameter. We extend the franchise fee contract to coordinate the decentralized decision situation. Contract design in franchising has already been addressed by several researchers. Important theoretical contributions include [30–33]. The approaches indicated above do not address contract design in franchising when private information is an issue [34]. The method used in the paper is similar to that of Liu et al. [35]. Liu et al. [35] investigated online dual channel supply chain system and its joint decisions on production and pricing under information asymmetry, and two kinds of contracts are designed for the decentralized system to coordinate the channel system. The main difference between [35] and this paper is the research problem.

In this paper, (a) When the retailer's scale parameter is a common information for the manufacturer, the manufacturer provides complete knowledge about the manufacturing cost to the retailer, which is required to pay a commission fee. We find the commission fee decreases as the retailer's scale parameter increases. That is, the high-scale-level retailer will pay less commission fee than the low-scale-level retailer. (b) When the retailer's scale parameter is his private information, the low-scale-level retailer may lie to pay less commission fee. To prevent the low-scale-level retailer lying, the manufacturer has to design a contract to reveal the retailer's private information. We design a menu of contracts with a principle-agent method under asymmetric information. By contrasting the centralized and decentralized decision situations, we can see that the maximal supply chain profits in two coordination situations are equal to that in the centralized situation and greater than that in the decentralized situation. Furthermore, under asymmetric information contract, the maximal expected profit obtained by the low-scale-level retailer is higher than that under symmetric information contract.

The organization of the paper is as follows. In Section 2, we present model assumptions and notations and then analyze price and sales effort decisions in the centralized and decentralized settings. Two types of supply chain contracts under symmetric and asymmetric information about retailer's scale parameter to coordinate the decentralized supply chain are designed in Section 3. To demonstrate the performance of contracts, a numerical example is presented in Section 4. Section 5 concludes with summary insights. For clarity of presentation, preliminaries and proofs of all propositions are relegated to the appendices.

2. Decision models

2.1. Model descriptions and assumptions

Consider a two-echelon supply chain consisting of a manufacturer and a retailer. The manufacturer wholesales a product to the retailer, who in turn retails it to the customers. The retailer needs to make his pricing and sales effort decision in order to achieve maximal expected profit. The manufacturer needs to decide the product's wholesale price to achieve his maximal expected profit. The following notations are used to formulate the supply chain model discussed in this paper.

p: unit retail price, which is the retailer's decision variable, satisfying $p > 0$;
θ: sales effort level, which is the retailer's decision variable, satisfying $\theta > 0$;
g: retailer's sales effort cost, which is a function of θ;
b: retailer's scale parameter, $b > 0$;
c: unit manufacturing cost;
w: unit wholesale price, which is the manufacturer's decision variable, satisfying $p \geqslant w$;
D: consumer's demand, which is a function of p and θ;
π_m: manufacture's profit, which is a function of w, p and θ;
π_r: retailer's profit, which is a function of w, p and θ;
π_c: profit of the total supply chain system, which is a function of p and θ.

Throughout the paper, the following assumptions are made: