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Coordinating supplier retailer and carrier with price discount policy

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ABSTRACT

Supply chain coordination with transport service providers (i.e., carriers) is seldom explored. This paper adds a carrier to a supplier–retailer system and analyzes the effect of the two sources of double marginalization on pricing policies. We assume that lead time demand is stochastic, and shortage during the lead time is permitted. In addition, we assume that the annual average demand rate is a decreasing function of the retail price. Our analysis shows that joint profit increases because demand increases, whereas unit operating cost decreases as a result of joint coordination. The analytical results for the decentralized and joint decision models are obtained for a specific annual average demand rate. Nonlinear transport-fee and wholesale-price discount schemes, which can facilitate supply chain coordination, are then obtained using the profit sharing method. Finally, numerical examples are presented for illustrative and comparative purposes.

1. Introduction

Coordination among disparate partners within the supply chain and e-supply chain is widely discussed, whereas supply chain coordination with transport service providers is seldom explored. In this paper, we add a carrier to a supplier–retailer system and analyze the effect of the two sources of double marginalization on pricing policies, which are profit margins of the retailer and carrier.

Most of the previous literature considered transport issues in supply chain decision took the assumption that the shipping costs were exogenously given. Thus, the effect of carrier profit margins on supply chain pricing and inventory decisions is not adequately reflected. In this paper, the carrier's shipping costs are assumed to be endogenous in supply chain decisions. We assume that lead time demand is stochastic, and shortage during the lead time is permitted. In addition, we assume that the annual average demand rate is a decreasing function of the retail price. This paper primarily aims to analyze the effect of double marginalization on pricing policies and to identify an incentive scheme to coordinate the supply chain including a carrier.

The two research areas related to this research are: (1) lot-size coordination for product supply chains and (2) supply chain coordination incorporating transportation issues in decisions. There are available reviews in the literature on lot-size coordination in supply chains (see, e.g., reference lists in [1–3]). The body of the literature on coordinating order quantities between entities in a supply chain focused on a two-level supply chain for different assumptions. One of the first lot-size models dealing with buyer–vendor coordination was proposed by Goyal [4], who analyzed a system consisting of a single

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vendor and a single buyer. He implicitly assumed that the vendor provides an infinite replenishment rate, and that the production lot is transferred to the buyer in equal-sized shipments. The Goyal's problem is referred to in the literature as the Joint Economic Lot-Sizing (JELS) problems. Among the works on the JELS problems, and of relevance to this paper, are those who considered all-unit discounts with joint buyer–seller perspective (see, e.g., reference lists in [5–7]). Other researchers (see, e.g., reference lists in [4,8,9]) investigated the JELS problems with quantity discounts by maximizing the profits of both the seller-buyer with a profit sharing mechanism. Li and Huang [10] explored the cooperative JELS problems with a quantity discount scheme and profit sharing mechanism. They suggested that the party that has a more powerful bargaining position would gain a higher fraction of the profits.

Few works have investigated the JELS problems in a three-level supply chain. Munson and Rosenblatt [11] are believed to be the first to investigate a three-level supply chain that consists of a supplier, a manufacturer and a retailer. In their model, the total demand was assumed to be constant and deterministic. Also, the manufacturer was assumed to be the most influential channel player who is able to obtain a quantity discount from the supplier and pass some or all of this discount quantity to the retailer. The work of Munson and Rosenblatt [11] was extended by Khouja [12], who considered a system consisting of a supplier, multiple manufacturers and multiple buyers. He dealt with three inventory coordination mechanisms between chain members and developed closed-form expressions or simple algorithms for solving each of the coordination mechanism models. Lee and Moon [13] developed inventory models for a three level supply chain with one supplier, one warehouse, and one retailer. They considered three types of individual models (independent model, retailer's point of view model, and supplier's point of view model) and applied the compensation policy for the benefits and losses to the coordinated inventory model. Their study was based on the assumption of constant and deterministic demand. Jaber et al. [14] studied the coordination of a three-level (supplier–manufacturer–retailer) supply chain, where the retailer was faced with price dependent demand. In their model, an all-unit price discounts scheme was used to coordinate the order quantities among the supply chain levels, and a profit sharing mechanism is used to maximize the supply chain profit. In the above-mentioned study, they assumed no shortages to occur and zero lead time.

Transport is a significant component of supply chain operations. Depending on the estimates used, upwards of 50% of the total annual logistics cost of a product can be attributed to transport. Therefore, any discussion on purchase quantities should consider transport costs [15]. There is substantial literature on incorporating transport costs in the JELS problems. Kim and Ha [16] developed a buyer–supplier coordination model to determine optimal order quantity and the number of deliveries in a simple JIT scenario, assuming that transport cost is fixed per delivery regardless of shipping weight. Ertogral et al. [17] explicitly incorporated the transport cost into the vendor–buyer lot-sizing problem and developed optimal solution procedures for solving the integrated models. They considered all-unit-discount transport cost structures with and without over-declaration. In their models, the total demand and production rates are assumed to be constant and deterministic. Sajadieh et al. [18] developed an integrated production inventory marketing model to determine the relevant profit-maximizing decision variable values when demand is price sensitive. Lee and Wang [19] addressed an integrated three-level JELS problem with freight rate discounts. Madadi et al. [20] addressed specific inventory management decisions with transportation cost consideration in a multi-level environment consisting of one supplier, one warehouse and several retailers.

In all the above mentioned models with transport costs consideration, exogenously given shipping costs are used. However, the carrier's decision-making has obvious effect on supply chain performance. Lei et al. [21] studied the optimal business policies for a supply chain involving a third party transport partner, a supplier and a buyer who faces a price-sensitive demand. They assumed that the transporter charges supplier a shipping rate, be responsible for transporting the product from the supplier to the buyer. In their model, discount schemes are not provided to coordinate the order quantities and prices among the supply chain levels. Furthermore, they also assumed no shortages to occur and zero lead time. Unlike the work of Lei et al. [21], this paper assumes all-unit price discounts, profit sharing mechanism, shortages to occur and stochastic demand during the lead time. This paper investigates the channel coordination issue of a supply chain with one supplier, one retailer, and one carrier. We assume that lead time demand is stochastic, and shortage during the lead time is permitted. Furthermore, we assume that the annual average demand rate is a decreasing function of the retail price. Similar to the work of Jaber et al. [14], this paper uses an all-unit price discounts scheme to coordinate the supply chain. Price discounts are often suggested as incentives to facilitate coordination (or collaboration) owing to the negative demand effect of double marginalization on supply chain management (see, e.g., reference lists in [22–24]). For a specific annual average demand rate, the present study demonstrates the effectiveness of transport-fee and wholesale-price discount schemes as a control mechanism in joint coordination among the carrier, supplier, and retailer.

This paper is organized as follows. After constructing the decentralized and joint decision models, we characterize the form of the optimal joint policy and discuss the impact of joint policy on the system's expected profit in Section 2. Section 3 illustrates the optimal policy for a specific annual average demand rate ($D(p) = a \cdot p^{-2}$). We develop a coordination mechanism of the supply chain in Section 4. Section 5 presents the numerical examples for illustrative and comparative purposes. Section 6 concludes the paper.

2. Model development

We consider a multi-period supply chain with one supplier, one retailer, and one carrier. The retailer purchases an item from the supplier, while the supplier orders integer multiple of the retailer's order quantity of items from his/her supplier. The carrier is responsible for transporting this item from the supplier to the retailer.