European Journal of Operational Research 203 (2010) 70–80

Contents lists available at ScienceDirect

European Journal of Operational Research

journal homepage: www.elsevier.com/locate/ejor

Production, Manufacturing and Logistics

Coordination mechanism for the supply chain with leadtime consideration and price-dependent demand

Haoya Chen [a], Youhua (Frank) Chen [b], Chun-Hung Chiu [c], Tsan-Ming Choi [c,*], Suresh Sethi [d]

[a] The IBM Research Center, Beijing, China
[b] Dept. of Systems Engineering and Engineering Management, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong
[c] Institute of Textiles and Clothing, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong
[d] School of Management, M/S SM30, The University of Texas at Dallas, P.O. Box 830688, Richardson, TX 75083-0688, USA

ARTICLE INFO

Article history:
Received 4 March 2008
Accepted 1 July 2009
Available online 7 July 2009

Keywords:
Supply chain coordination
Leadtime
Information updating
Return policy
Newsvendor problem
Risk and profit sharing
Price-dependent demand

ABSTRACT

We study a coordination contract for a supplier–retailer channel producing and selling a fashionable product exhibiting a stochastic price-dependent demand. The product's selling season is short, and the supply chain faces great demand uncertainty. We consider a scenario where the supplier reserves production capacity for the retailer in advance, and permits the retailer to place an order not exceeding the reserved capacity after a demand information update during a leadtime. We formulate a two-stage optimization problem in which the supplier decides the amount of capacity reservation in the first stage, and the retailer determines the order quantity and the retail price after observing the demand information in the second stage. We propose a three-parameter risk and profit sharing contract that coordinates the supply chain. The proposed contract permits any agreed-upon division of the supply-chain profit between the channel members.

1. Introduction

One of the main challenges in the management of a supply chain of short-lifecycle products is to balance product availability to service demand and low inventory to avoid product obsolescence. There are three important decisions that the supply chain must make: the quantity of key materials to be procured or the production capacity to be reserved, the amount to be produced, and the price to be charged. The first decision is based on early demand information, and the last two are made after more accurate demand information becomes available. In a decentralized supply chain with one supplier and one retailer, the decisions are usually made by the two parties sequentially: the supplier reserves the production capacity and secures key materials well before the selling season, and the retailer specifies the order and determines the selling price only after a demand forecast update. This scenario is well-observed in the fashion industry. For example, various Hong Kong based fashion retailers, such as Giordano and Bossini, have established a long term relationship with various garment factories in the mainland China. In some of these fashion retailers, they will work with the factories for joint production planning. For example, Giordano understands the importance of supply chain partnership and communicates with some garment factories on the upcoming season's quantity before the season starts. Many factories need to reserve some amount of production capacity for Giordano in advance after the discussion. In some cases, Giordano even commits some necessary components such as fabrics and will advise the factories to order some quantity in advance because the leadtime for ordering fabrics can be very long. In such a supply chain, optimal system-wide performance requires the execution of a precise set of actions. However, these decentralized actions often result in poor performance and are generally not in the best interests of the channel members. Nevertheless, optimal performance can be accomplished if the supply chain members coordinate with each other by designing certain contracts so that each member's profit maximization effort is aligned with the overall objective of the supply chain.

The demand uncertainty of a short-lifecycle product consists generally of two parts: the unknown market reception of the new product and the inherent randomness. The uncertainty in the market acceptance of the product arises from the fact that the product is new and

* Corresponding author.
E-mail addresses: yhchen@se.cuhk.edu.hk (Y. (Frank) Chen), tcchiu@inet.polyu.edu.hk (C.-H. Chiu), tcjason@inet.polyu.edu.hk (T.-M. Choi), sethi@utdallas.edu (S. Sethi).

0377-2217/$ - see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.ejor.2009.07.002

there are perhaps other competing new products, and it may be reduced as more information is revealed (e.g., through earlier trade shows or trial testing). Inherent noise, on the other hand, is always present even for products with sales histories. Bearing these two kinds of uncertainties in mind, we model a two-stage dynamic decision-making problem as follows. With a prior knowledge about the market, the supplier determines how much capacity to reserve (in the first stage). After a certain leadtime during which the firms (the supplier and the retailer) update the demand information (in the second stage), the retailer chooses the order size and the selling price, in order to maximize his profit. Just before the selling season starts, the supplier completes production and makes delivery to the retailer, who then sells the product in the market at the decided price. The retailer's order size is limited by the capacity reserved in the first stage, and any excess capacity and leftover inventory at the end of the selling season are salvaged. In short, the problem we consider in this paper concerns capacity reservation, information revision, and a stochastic price-dependent retail demand.

We propose a coordinating contract for the supply chain. The contract aligns the two self-interested parties so their decentralized actions maximize the whole supply chain. By leaving the capacity reservation decision to the supplier, we propose a risk and profit sharing mechanism with which the retailer bears part of the risk from the supplier's over-reserved capacity. As a result, although the retailer is permitted to specify his order as well as the retail price after observing the market information, he still shares the risk of the initial capacity reservation by the supplier. At the same time, the retailer also benefits from the supplier's action of reserving sufficient capacity in advance. We show that this risk and profit sharing mechanism, together with a return policy (Pasternack, 1985), can resolve the problem of double marginalization (Spengler, 1950) and thus coordinate the supply chain under some appropriate settings. This contract is also flexible in the sense that it allows any given profit allocation between the channel members.

The remainder of the paper is organized as follows. In Section 2, we review the literature related to information updating, coordination, and pricing in supply chain management. In Section 3, we describe the model in detail, including the basic assumptions and the decision structures. We also analyze the decisions in the centralized system, which provides a benchmark for further discussion on the decentralized system. In Section 4, we propose a three-parameter risk and profit sharing contract and analyze the channel members' decisions under a decentralized system. A numerical analysis is carried out in Section 5. We conclude the paper in Section 6.

2. Literature review

Supply chain management and its coordination have received a great deal of attention in the last two decades. Supply chain management refers to the management of a multi-echelon system with product, information, and resource flows. In a centralized supply chain, information is public to all echelons and information flow is smooth, and there is a central planner who makes all the decisions. Optimal decisions which maximize the system-wide supply-chain profit can hence be made. On the other hand, in a decentralized supply chain, the entities are separate and each often only considers its own profit. Double marginalization (Spengler, 1950) takes place, leading to an inefficient supply chain. In order to improve supply chain efficiency, the supply chain entities can form a partnership via setting an appropriate contract. A contract that results in decisions by individual parties that maximize the profit of the entire supply chain and leaves each member of the chain satisfied is called a coordinating contract. In the literature, various policies for supply chain coordination have been proposed. Among them, the idea of setting a supply chain contract between individual parties has received much attention in recent years. A comprehensive review of supply chain contracts can be found in Cachon (2003).

The market is full of randomness and demand is highly uncertain. This is especially prominent in the case of new products. In making inventory decisions, it is often impossible to have perfect knowledge about the demand before the selling season commences. In general, a firm can learn about the demand (or other relevant variables) by observing some market signals. In the literature, the use of information for inventory problems dates back to the 1950s (e.g., Dvoretzky et al., 1952, Scarf, 1959). Latter published works studying inventory decisions with the use of information include Muth (1960), Murray and Silver (1966), Azoury (1985), Lovejoy (1990), Fisher and Raman (1996), Iyer and Bergen (1997), Sethi et al. (2004), Choi et al. (2003, 2006), Choi (2007), Mathur and Shah (2008), and Sethi et al. (2005). In what follows, we review some of the works especially related to our discussions on the use of information for supply chain management.

Donohue's (2000) paper is the most relevant to our work. She considers a system with two production modes – one costs less and has a longer production leadtime and the other costs more and has a shorter leadtime. She designs a contract with a price premium and a buy-back commitment, with which the retailer has an opportunity of placing an initial order and an additional order after obtaining a demand forecast update. Donohue shows that this mechanism can coordinate the decentralized system. Moreover, the contract is flexible in the sense that it admits any specific allocation of the total supply-chain profit to the channel members. Another relevant work is that of Barnes-Schuster et al. (2002), which deals with a two-stage correlated demand model. The buyer purchases an option besides placing a firm order at the start. After the demand is realized in the first stage, the buyer can partly execute the option to satisfy the demand in the second phase. Mathur and Shah (2008) also consider a two-stage supply chain coordination problem, in which the supplier decides the production quantity before the demand is realized. Mathur and Shah propose to apply the contract with two-way penalties to coordinate the supply chain. Conditions of the contract for achieving supply chain coordination are derived separately for the cases when demand follows an uniform distribution and when production capacity is jointly decided by both parties of the supply chain. There are several papers on supply chain optimization and information updating without considering supply chain coordination. Examples include papers dealing with Quick Response (e.g., Iyer and Bergen, 1997), Accurate Response (e.g., Fisher and Raman, 1996), and Capacity Reservation (e.g., Brown and Lee, 1997). These works assume that the selling price is exogenous. However, in reality, most of the sellers have the right to set their own selling price, which can directly affect the market demand. Thus, in a price-endogenous setting, the decision which maximizes the expected profit should be determined jointly with respect to the inventory level and the selling price.

Because of the complexity of the decision based on both the price and the stock level, the coordination in the case of the price-endogenous scenario has not been fully studied. It is the purpose of this paper to include the pricing decision in a supply chain coordination model, and develop additional insights from this inclusion. In what follows, we review some recent works that study supply chain coordination with joint pricing and stocking decisions.

Cachon (2003) analyzes various popular supply chain coordinating contracts and explains why the popular contract forms, such as the sales-rebate contract (e.g., Taylor, 2002), the buy-back contract (e.g., Pasternack, 1985; Emmons and Gilbert, 1998), and quantity discounts (Wang, 2005), are unable to coordinate the supply chain when there is a price-dependent demand. A price discount sharing (PDS) contract