Omega 37 (2009) 811 – 825

Contents lists available at ScienceDirect

Omega

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

Sharing inventory risk in supply chain: The implication of financial constraint☆

Guoming Lai[a,*], Laurens G. Debo[a], Katia Sycara[b]

[a]Tepper School of Business, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA 15213, USA
[b]Robotics Institute, Carnegie Mellon University, Pittsburgh, PA 15213, USA

ARTICLE INFO

Article history:
Received 13 April 2007
Accepted 4 June 2008
Available online 23 August 2008

Keywords:
Newsvendor model
Stackelberg game
Preorder
Consignment
Bankruptcy

ABSTRACT

A supply chain may operate under either preorder mode, consignment mode or the combination of these two modes. Under preorder, the retailer procures before the sale and takes full inventory risk during the sale, while under consignment, the retailer sells the product for the supplier with the supplier taking the inventory risk. The combination mode shares the risk in the supply chain. The existing research has examined the supply chain modes from various operational aspects. However, the impact of financial constraint is neglected. This paper examines the impact of financial constraint and investigates the supply chain efficiency under each mode. Based on a Stackelberg game with the supplier being the leader, we show that without financial constraint the supplier always prefers the consignment mode, taking full inventory risk. Whereas, in the presence of financial constraint, the supplier will sell part of the inventory to the retailer through preorder, which shares the inventory risk in the supply chain. We show that with financial constraint, the combination mode is the most efficient mode even if the retailer earns zero internal capital.

1. Introduction

Firms hold inventory to satisfy consumer demand, which generates revenue. However, under various market uncertainties, firms that carry inventory may face significant risk. Inventory can turn out to be of little value in the case of overage. For instance, with an unexpected demand decline, Cisco Systems Inc. wrote off $2.25 billion excess inventory in 2001 [1]. In a supply chain, the allocation of inventory risk varies in different situations. Some firms may avoid taking the risk by transferring it to the others. Consider a supplier and a retailer. The supplier may sell the inventory to the retailer by enforcing preorder so that the retailer needs to procure before the production and carry the inventory during the selling season (called *preorder mode*). In contrast, the supplier may also offer consignment, where the retailer sells the product for the supplier for some commission (called *consignment mode*). A supply chain may also be operated under a combination of the above two modes so that the risk is shared among the firms (called *combination mode*). One can easily find examples in practice for these supply chain modes. For instance, Cachon [2] discusses two cases in sporting goods industry: Trek Inc. that produces bicycles applies a consignment mode by holding all the inventory itself and the retailers sell the product for Trek Inc., while O'Neill Inc. that produces sporting apparels offers both preorders and consignment orders to the retailers. In another example provided by Netessine and Rudi [3], the three major wholesalers, Alliance Entertainment Corp., Ingram Entertainment and Baker & Taylor in the business of distributing home entertainment products, all offer drop shipping channels. Under such a channel, the retailers do not hold any inventory. After they receive the orders from consumers, they

☆ This manuscript was processed by Area Editor B. Lev.

* Corresponding author. Tel.: +1 412 681 0958.
E-mail address: guomingl@andrew.cmu.edu (G. Lai).

0305-0483/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.omega.2008.06.003

pass them to those wholesalers who then directly ship the products to the consumers.

With different allocation of the inventory risk, firms in a supply chain may install different inventory levels which influence the efficiency of the supply chain. Therefore, which supply chain mode shall be adopted under a given environment deserves a close examination. There is a stream of literature in Operations Management which has investigated this problem: for instance, Cachon [2] focuses on the demand uncertainty and addresses how the firms, one supplier and one retailer, will invest inventory under each supply chain mode; Netessine and Rudi [3] address a similar problem, but in addition consider the effect of the retailer's advertising effort; Netessine and Rudi [4] extend this problem with considering one supplier and multiple retailers; etc.

However, the existing research mainly focuses on sole operational aspects but neglects financial concerns that firms may face when deciding the supply chain mode. In practice, many firms are capital constrained, especially for start-up firms, growing firms and the firms in the traditional sector with heavy investment and low margin. Those firms often need to finance their operations from external capital markets through short-term loans or issuing corporate bonds. For example, according to Lester [5], Delphi, a S&P 500 company, had $17.1 billion in assets while $22.2 billion in debt around 2002. Financial structure and operational decisions usually cannot be separated under an imperfect capital market with various frictions such as administration cost on loan and bond issuing, taxes, bankruptcy cost, accounting cost, etc. When banks or individual investors determine the fee for capital lending, they are generally concerned of the default risk. If the uncertainty of the return is high, the fee will be high. This, in loop, will influence the firms' operational decisions when their business is risky.

In this paper, we study the impact of financial constraint on the efficiency of the supply chain modes. We focus on a supply chain with one supplier and one retailer, where the supplier acts as a Stackelberg game leader. The supplier (he) moves first who determines which supply chain mode he will use: to enforce preorder, to offer consignment, or to offer both. The supplier provides the wholesale price for the preorder and/or the commission for the consignment order. Given the supplier's decision and offer, the retailer (she) determines how many units of the product to procure. Both of the firms are risk neutral and they optimize their own profits when they make their decisions. We assume that the consumer demand is uncertain when the firms determine the supply chain mode, the contract and the ordering quantity, and will be realized only after the inventory decision is made. In other words, the inventory decision and the sales format follow the classical newsvendor form. However, in this paper, we assume that the firms may have internal capital constraint; i.e., they may not have sufficient capital to install the ideal inventory level. In such a situation, we assume that both of the firms can access to an external financial market from which they can borrow a loan. Nevertheless, since the potential demand is stochastic, there exists risk that the firms may not be able to repay the debt if the sales are low and then will be forced into bankruptcy. We assume that the bankruptcy procedure is costly so that only a part of the firm value can be recovered. As a result, the financial market may charge a premium when issuing the loan. We evaluate the efficiency of the three supply chain modes in such an environment.

This paper generates several managerial insights. From the perspective of the supplier, we show that without any capital constraint, the supplier always prefers the consignment mode which operates most efficiently. However, if the supplier is capital constrained, he will choose the combination mode, offering both preorder and consignment order. To share the inventory investment between the supplier and the retailer can lower the inventory risk and thus reduce the financing cost even if the retailer is highly capital constrained. Our results shed light on supply chain choices in practice if firms have internal capital limit, which complements the existing literature.

The remainder of the paper is organized as follows. In Section 2, we review the related literature. Section 3 presents the model. In Section 4, we first analyze a benchmark for the model where the firms do not have capital limit, and then examine the firms' operational and financial decisions with capital constraint. In Section 5, we conclude.

2. Literature review

Our paper relates to two bodies of literature: the literature on supply chain contracting and the literature on operations with financial concerns.

Supply chain contracting has been thoroughly studied in Operations Management. We review those papers that are closest to ours in terms of the modeling approach and analysis. Lariviere and Porteus [6] study a model with one supplier and one retailer. The supplier uses a single wholesale price contract and sells the product to the retailer before the demand information is revealed. They explore the optimal wholesale price contract for the supplier and examine the supply chain efficiency. This supply chain form corresponds to our preorder mode. Cachon [2] investigates three contracts: push, pull and advance-purchase discount in a supply chain with one supplier and one retailer. In the push contract, the supplier only offers "prebook" order, while in the pull contract, the retailer places "at-once" order after she observes the demand. In the advance-purchase discount contract, the retailer prebooks with discount as well as places at-once order if there is excess demand after the demand is realized. Cachon compares the efficiency of those contracts and identifies the Pareto set of the wholesale prices for each contract. He shows that if it is possible for the firms to consider advance-purchase discounts, the supply chain can always be coordinated with the arbitrary allocation of its profit depending on the setting of discounts. Netessine and Rudi [3] similarly address the above problem by comparing the traditional wholesale channel and the drop shipping channel. However, in their model, the retailer needs to exert advertising effort to acquire demand. They demonstrate that both channels are suboptimal and show how decision power in the supply chain affects the decision variables and profits. Netessine and Rudi [4] extend this problem and consider one supplier with multiple retailers. They show that each