Int. J. Production Economics 151 (2014) 112–120

Contents lists available at ScienceDirect

Int. J. Production Economics

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

Risk hedging in a supply chain: Option vs. price discount

Zhongyi Liu [a], Lihua Chen [b], Ling Li [c], Xin Zhai [d,*]

[a] School of Police Administration, People's Public Security University of China, Beijing 100038, China
[b] Guanghua School of Management, Peking University, Beijing 100871, China
[c] College of Business & Public Administration, Old Dominion University, Norfolk, VA 23529, USA
[d] Guanghua School of Management, Peking University, Beijing 100871, China

ARTICLE INFO

Article history:
Received 16 July 2012
Accepted 17 January 2014
Available online 14 February 2014

Keywords:
Risk hedging
Option contract
Advance Purchase Discount contract
Loss-averse supplier

ABSTRACT

In this research, two risk hedging strategies, the option contract and the advance purchase discount contract, are investigated within a manufacturer–retailer two-echelon supply chain context. This study offers three contributions. First, the optimal decisions under the two contracts from the perspectives of both the manufacturer and the retailer are determined. Second, circumstances under which supply chain coordination can be reached are identified. Third, the scenario of loss-averse manufacturer has been explored. The results of the analysis provide practical insights to the manufacturer when she plans production quantity and to the retailer when he replenishes inventory.

1. Introduction

The global competition has enhanced the time-to-market performance, shortened product life-cycles, increased time-sensitive customer demand, and popularized outsourcing in supply chain. To deal with these challenges, supply chains are becoming more responsive to market needs (Chen et al., 2012; Li et al., 2012; Li, 2012). For instance, long lead-time is a fairly common phenomenon in many industries. Long lead-time increases variability in demand and supply which requires more inventories in the supply chain system. In the apparel industry, the lead-time between retailer ordering and manufacturer delivering can be as long as 12 months (Fisher and Raman, 1996). In the toy industry, order fulfill lead-time can be as long as 18 months (Biyalogorsky and Koenigsberg, 2006). Retailers usually place their orders long before the demand is there because manufacturers need to build up capacity, plan production schedule, and purchase raw materials before they can produce the orders (Xu et al., 2012). Given long order fulfillment lead-time and high uncertainty in consumer demand, the matching between supply and demand is very challenging. The Bullwhip effect, which describes the distortion of the demand information as it is passed on from the retailer to the upstream manufacturer, is a typical phenomenon in the supply chain. According to Accenture's report,[1] in the energy industry, from 2006 to 2010, the production quantity of ethanol and biodiesel in the European Union is not consistent with the consumption quantity. The mismatch between supply and demand usually leads to increased inventory-related cost and lost profit. For example, in early 2001, Cisco Systems built a lot of inventory for a booming market, but they failed to predict the market downturn. As a result, Cisco Systems was forced to write-off 2.25 billion US$ in inventory in May 2001.

To reconcile the mismatch between supply and demand, manufacturers (suppliers) would like the retailer to place orders as early as possible. The Advance Purchase Discount (APD) contract is one of the means that encouraging retailers to place their orders early. The APD contract was originally introduced between retailers and customers, and then used as a contract between suppliers and retailers (Prasad et al., 2010). Under the APD contract, the supplier offers the retailer with two wholesale prices: (i) a discount price if the retailer places orders before the selling season starts and (ii) a regular price if the retailer buys during the selling season. The retailer bears the inventory cost if he orders the product before the selling season starts and the opportunity cost on any lost margins because his orders may not be fulfilled during the selling season. On the other hand, the supplier bears the risk on any production in excess of the retailer's order quantity. Under the APD contract, the manufacturer's production decision has a significant impact on the allocation of supply chain risks, as the APD contract allows for intermediate allocations of inventory risks between supply chain partners.

The option contract, a popular method applied by practitioners to cover the discrepancy between supply and demand, was first introduced in the financial area. The option contract specifies a contract between two parties for a future transaction on an asset. Later, it was applied to the supply chain area as a means of hedging

* Corresponding author. Tel.: +86 10 62757460; fax: +86 10 62753182.
E-mail addresses: Liuzhongyi@ppsuc.edu.cn (Z. Liu), chenlh@gsm.pku.edu.cn (L. Chen), lli@odu.edu (L. Li), xinzhai@gsm.pku.edu.cn (X. Zhai).

[1] Blending biofuels in the European Union, Accenture report, 2010.

http://dx.doi.org/10.1016/j.ijpe.2014.01.019
0925-5273

Table 1
Risks shared by both parties under the APD contract.

Demand interval	Supplier's risk	Retailer's risk
$d < y$	Leftover	Leftover
$q \geq d \geq y$	Leftover	Stockout
$d > q$	N/A	Stockout

Table 2
Risks shared by both parties under the option contract.

Demand interval	Supplier's risk	Retailer's risk
$d < q$	Leftover	N/A
$y \geq d \geq q$	Stockout	N/A
$d > y$	N/A	Stockout

risks that stem from uncertain demand. Under the option contract, the option buyer (the retailer) gains the right, but not the obligation, to engage in the transaction, while the seller (the manufacturer) incurs the corresponding obligation to fulfill the transaction. Under the option contract, the manufacturer bears the inventory risk and the retailer pays the option fee. Both European option and American option are common in the market. A European option may be exercised only at the expiration date of the option, while an American option may be exercised at any time before the expiration date. In this paper, we focus on the European option for the reason of tractability.

To further understand the risks born by both parties under the APD contract and the option contract, we study a two echelon supply chain consisting of one manufacturer and one retailer. Under the APD contract, before the selling season starts, the manufacturer announces the discount price and the retailer places its initial order. Based on the order quantity, the manufacturer determines the production volume accordingly. After the selling season starts, the retailer may replenish its inventory from the manufacturer at the regular price if the product sells fast. Finally, the manufacturer delivers the order in a whole lot. Table 1 summaries the risks shared by the manufacturer and the retailer under the APD contract. The term d denotes the realized demand, q the manufacturer's production quantity, and y the retailer's order quantity.

When the APD contract is offered, a rational manufacturer may produce a quantity q greater than the retailer's order quantity y, because the retailer may order more products during the selling season at a higher price if the demand is greater than the retailer's initial order. From the manufacturer perspective, only when the actual demand is less than its production quantity, it will bear the cost of extra inventory (scenario 2 in Table 1). From the retailer's perspective, if the actual demand d is less than its order y, the retailer bears the cost of extra inventory (scenario 1 in Table 1). However, if the actual demand d is greater than the retailer's order y, the retailer will lose profit margin due to stockouts (scenario 3 in Table 1).

Under the option contract, the manufacturer optimizes its option price and the retailer chooses to buy a quantity of the option before the selling season. The manufacturer, then, decides production quantity accordingly. After the selling season starts, the retailer may exercise any portion of its options to fulfill demand and the manufacturer delivers.

Table 2 summarizes the risks shared by the manufacturer and the retailer under the option contract. When the option contract is offered, a rational manufacturer would produce a quantity q that is no greater than the retailer's order y, as there is a probability that the retailer may not exercise his options at all. In this case, it would be optimal for the manufacturer to produce no more than the quantity ordered by the retailer, and purchase the additional order quantity from the retailor after the selling season starts from a third-party source if necessary. From the supplier's perspective, if the realized demand d is less than the manufacturer's production quantity, the manufacturer will hold extra inventory (scenario 1 in Table 2). If the realized demand d is greater than the manufacturer's production quantity, the manufacturer has to supplement for the stockout up to a limit of y (scenario 2 in Table 2). From the retailer's perspective, there will be a lost profit margin due to the stockout only when the realized demand is greater than its order quantity y (scenario 3 in Table 2).

In general, the APD contract is beneficial to the manufacturer and the option contract is beneficial to the retailer. Under the APD contract, the retailer tends to order more and thus bears more inventory risk. However, will the manufacturer always be in favor of the APD contract? To address this issue, we have studied both the APD contract and the option contract to understand the best scenario to adopt these two contracts respectively. Our results show that only when the retailer's initial purchase quantity is no greater than a threshold value, the manufacturer would prefer the APD contract to the option contract. Intuitively, the option contract offers more flexibility to the retailer as it compares to the APD contract which pushes all (or part) of the inventory risk to the retailer at a predetermined lower price.

This research offers three contributions. First, the optimal decisions under the two contracts from the perspectives of both the manufacturer and the retailer are determined. Second, circumstances under which supply chain coordination can be reached are identified. Third, the scenario of loss-averse manufacturer has been explored. To the best of our knowledge, this is the first work that considers the loss-averse attitude, especially from the manufacturer's point of view.

The reminder of this paper is organized as follows. Section 2 provides the background knowledge and related literature. Section 3 presents the model. Section 4 considers the case when both parties are risk neutral. Section 5 considers the case when the supplier is loss-averse. Section 6 summarizes our results and concludes the paper.

2. Literature review

Our work integrates the research streams on option contract and APD contract since both contracting strategies can be beneficial to the supply chain partners under different situations. The published literature indicates that options (Barnes-Schuster et al., 2002; Chen et al., 2014) or option-like contracts, such as buy-back contract (Emmons and Gilbert, 1998; Wu, 2013), backup contract (Eppen and Iyer, 1997) and quantity flexibility contract (Tsay, 1999) can provide both manufacturer/suppliers and retailers with flexibility to share the demand risks thus improve supply chain performance. Based on the classical newsvendor problem, Xu (2006) considered a class of multi-period flexible supply policies with options and characterized the optimal options ordering policy. Chen and Parlar (2007) explored the single-period inventory model with a put option and stochastic demand. They showed that by choosing the strike price or strike quantity optimally the newsvendor could reduce the uncertainty of his profit margin. Burnetas and Ritchken (2005) investigated the role of option contracts with downward sloping demand curve in a supply chain context. They showed that the introduction of option contracts causes the wholesale price to increase and the volatility of the retail price to decrease. Wu and Kleindorfer (2005) analyzed integrating contract procurement with capacity options and