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Channel coordination with a loss-averse retailer and option contracts

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ABSTRACT

We investigate a one-period two-echelon supply chain composed of a risk-neutral supplier that produces short life-cycle products and a loss-averse retailer that orders from the supplier via option contracts and sells to end-users with stochastic demand in the selling season. When a single retail season begins, the retailer can obtain goods by purchasing and exercising call options. We derive the loss-averse retailer's optimal ordering policy and the risk-neutral supplier's optimal production policy under these conditions. In addition, we find that the loss-averse retailer may order less than, equal to, or more than the risk-neutral retailer. Further, we show that the loss-averse retailer's optimal order quantity may increase in retail price and decrease in option price and exercise price, which is different from the case of a risk-neutral retailer. Finally, we study coordination of the supply chain and show that there always exists a Pareto contract as compared to the non-coordinating contracts.

1. Introduction

The rapid and unpredictable changes in today's global market, coupled with increasing competition, speedy technological advancement, heightened expectations of customers, and the shortening of product life cycles, enterprises have been forced to invest in and pay increasingly more attention to their supply chains (Li et al., 2011a, 2011b, 2013; Ma et al., 2011; Xu, 2011a, 2011b; Xu et al., 2007, 2012; Jiang et al., 2013). A number of companies have found that, in general, supply chain management initiatives have substantially increased revenue, decreased costs, and improved responsiveness to demand (Li, 2011). In some industries, supply chain management plays the most important part in the success of a firm (Li, 2011; Xu, 2011). However, as supply chains have become more complex and geographically dispersed, often involving a network of suppliers around the world, there are new risks in matching supply and demand. If the order quantity is lower than realized demand, the company will not be able to fully satisfy demand and will face the costs of damaged customer relationship. If the order quantity is higher than it, the company loses money on excess products given the short life cycle assumption. However, forecasting the right quantities of the right products is close to impossible, so matching supply to demand has become a major risk management issue faced by global supply chains. To manage and hedge against this risk, option contracts are efficient instruments and are becoming increasingly popular in supply chain management. Option contracts can help the retailer ensure supply and pricing to meet uncertain future demands, and also provide the flexibility on the quantity of products to purchase when further demand information is available. At the same time, option contracts can attract the supplier as well since revenue is received at the outset. In fact, option contracts have been widely adopted in many industries such as toys (Barnes-Schuster et al., 2002), electronics (Billington, 2002) and aerospace (Cole, 1998). For example, option contracts are employed in 35% of Hewlett-Packard's (HP) procurement value. Particularly, its purchases of memory chips involve option contracts with its suppliers (Fu et al., 2010). Boeing offers option contracts to airlines for the purchase of aircrafts (Cole, 1998).

In recent years, more and more attentions from scholars and practitioners are paid to manufacturing in China which is the biggest manufacture center of the world. In order to answer “What are the fundamental steps for China's success in manufacturing as China's manufacturing sector has been growing at a much faster clip than in the US?”, many researchers have tried their best from different views at the tactics and technology levels, such as the effects of enterprise information technology (Li, 2012, 2013; Li and Zhou 2013), the adoption of transshipment policy under VMI environment (Chen et al., 2012a, 2012b), and the population of simulation technology (Chen and Zhou, 2010; Zhou et al., 2010). Recently, we have visited many industries in China (e.g. food

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processing industry, automobile industry and electrics manufacturing industry) and find that more and more manufacturing enterprises adopt option contracts to hedge supply chain's risks from stochastic demand, fluctuant price and unreliable supplies. So, option contracts may also play a crucial part in the success of China's manufacturing risk management. Recently, Chen and Shen (2012) are motivated by Chinese manufacturing practice and investigate a one-period two-party supply chain with option contracts and service requirements. They developed supply chain models that incorporate both option contracts and a service requirement, and provided insights into the influence of option contracts on supply chain decisions and performance. They showed that option contracts are a useful tool to hedge operation management risks and can benefit both the retailer and supplier.

In most supply chain models, decision makers are supposed to be risk-neutral and to maximize profit (or the expected profit in an uncertain environment) (Xing et al., 2013). But many experimental studies and observations of managerial decision-making under uncertainty (MacCrimmon and Wehrung, 1996; Fisher and Raman, 1996; Schweitzer and Cachon, 2000; Ho and Zhang, 2008; Feng et al., 2011) showed that decision-making behaviors of managers deviate from maximizing (expected) profit and were consistent with loss aversion. Loss aversion, which is one of the key features of the Prospect Theory (Kahneman and Tversky, 1979), means that people are more sensitive to losses than to same-sized gains, and the perception of gains or losses is related to the reference point. At the same time, from the behavioral theory's viewpoint, the leader, such as the large supplier, can diversify its assets across multiple firms and is risk-neutral, while the follower, such as small retailer, whose security of its business and income is related to the principal, is loss-averse (Wiseman and Gomez-Mejia, 1998). Motivated by these experiments and observations, and the current industry environment, we analyze in this paper a one-period two-echelon supply chain which is composed of a risk-neutral supplier and a loss-averse retailer with option contracts.

Several questions can be asked of this model:

(1) What is the loss-averse retailer's optimal ordering quantity and what is the risk-neutral supplier's optimal production policy in the presence of option contracts?
(2) What effect does loss-averse have on a retailer's optimal ordering policy?
(3) What is the effect of change in price and cost parameters on the loss-averse retailer's decision making?
(4) How can the supply chain be coordinated with a loss-averse retailer and option contracts?

The main contributions of our work are as follows:

(1) We develop supply chain models that incorporate both a loss-averse retailer and option contracts. Our paper provides insights into the effect of loss-averse on decision making and performance of the supply chain.
(2) We derive the loss-averse retailer's optimal ordering policy and the risk-neutral supplier's optimal production policy with option contracts.
(3) We discuss the effect of loss aversion and variations in cost and price on the loss-averse retailer's decision making, and report many interesting results that have never been found to occur in risk-neutral cases.
(4) We also derive conditions which can coordinate the supply chain with a loss-averse retailer and option contracts. In addition, we derive that there always exists a Pareto contract.

The remainder of this paper is organized as follows. Section 2 presents the survey of related literature. Formulation of the model and assumptions are presented in Section 3. In Section 4, we discuss the optimal ordering policy of the loss-averse retailer with option contracts, and the effect of loss aversion and change in price and cost on the loss-averse retailer's decision making. In Section 5, we discuss the risk-neutral supplier's production policies in the presence of option contracts. Conditions for supply chain coordination are considered in Section 6. We conclude our findings and highlight possible future work in Section 7.

2. Literature review

Here, we discuss supply chains with loss-averse agents and option contracts. To highlight our contributions, we review only the most representative and relevant literature to our study.

First, we discuss papers that address the employment of option contracts in supply chain management. Barnes-Schuster et al. (2002) adopted a two-period model with correlated demand to investigate the role of option contracts in a buyer–supplier system, and got sufficient conditions and the corresponding linear transfer prices which can achieve channel coordination. Burnetas and Ritchken (2005) studied the role of option contracts in a supply chain with the demand curve sloping downward. They showed that if the manufacturer adopts option contracts which shift part of the quantity risk away from the retailer, then the equilibrium prices adjust correspondingly, which benefits the manufacturer but may help or harm the retailer. Wang and Liu (2007) proposed an option contract model to study the coordination and risk sharing issues in a retailer-led supply chain where the powerful retailer coordinates initiatively the manufacturer's production quantity. They investigated a coordination contract based on an option contract with two parameters and derived the coordination conditions. Recently, Zhao et al. (2010) considered the coordination issue with a cooperative game approach in a manufacturer–retailer supply chain with option contracts. They presented an option contract model and demonstrated that option contracts compared to the wholesale price contract can coordinate the supply chain and bring about Pareto-improvement. Xu (2010), in his study of management issues of production and procurement in a decentralized supply chain composed of one supplier and one manufacturer, supposed that the production yield, the wholesale price, and the market demand are uncertain. He derived the supplier's optimal production policy and the manufacturer's optimal option order policy, and showed that both the supplier and the manufacturer could get benefit from option contracts. Fu et al. (2010) investigated the optimal portfolio procurement policies taking into consideration random demand and spot price in a single-period supply chain. These papers studied the supply chain with option contracts from different angles, but they also assumed that the supply chain's agents are risk-neutral and their decision biases (such as loss-averse) have not been considered.

Next, we discuss the literature on supply chain management with loss-averse agents. As far as we know, Schweitzer and Cachon (2000) studied in the first place a loss-averse newsvendor issues. They derived that a loss-averse newsvendor without shortage cost will order strictly less than a risk-neutral newsvendor, and the optimal order quantity decreases in the degree of loss aversion. Wang and Webster (2007) considered a decentralized supply chain where the single manufacturer sells a perishable product to the single retailer with stochastic demand. They investigated the role of a gain/loss (GL) sharing provision, which makes the retailer order quantity and total supply chain profit go down and mitigates the loss-aversion effect. They also presented distribution-free GLB contracts which can achieve supply chain coordination and distribute arbitrarily the expected supply chain profit between the