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Impact of the downside risk of retailer on the supply chain coordination

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ABSTRACT

This paper analyzes the coordinating mechanisms for a single-period supply chain comprising of one supplier and one retailer. The later is constrained by downside risk. We model the decision problems with the newsvendor model, and then analytically derive the optimal order policies of the retailer. We have analyzed several often used coordinating mechanisms under retailer downside risk constraint. We find that none of the price-only contract, returns policies contract and revenue sharing contract can coordinate a supply chain with retailer's downside risk constraint. However, by integrating the transfer payment contract with returns policy contract and the revenue sharing contract, perfect coordination is possible. For optimal decisions of the supplier, we use the numerical method to analyze the effect of the retailer downside risk on decision variables, and profits of the supplier and the retailer. Compared with the case of no risk constraints, the study has shown that the splitting of the expected channel profits between the supplier and the retailer is dependent on the retailer's risk attitude. The more risk-reverse the retailer is, the lower are the profits earned by the retailer and, of course, the more are the profits of the supplier. We close with a discussion of contract implementation issues and future research.

1. Introduction

Most previous studies of supply chain contracts assume the decision-makers are risk neutral (Eeckhoudt, Gollier, & Schlesinger, 1995; Xiao & Xu, 2014; Rajesh & Ravi, 2015; Sawik, 2016; Wu, Kleindorfer, & Zhang, 2002). In practice, however, due to increased globalization and vertical integration, supply chains are becoming quite complex and potentially vulnerable and that lead to the decision-makers are usually risk averse. Examples of supply chain risk are reported from both the practice and the scholars. For example, Ericsson lost 400 million Euros after their semiconductor supplier located in Mexico caught on fire in 2000 (Tang, 2006). Taiwan earthquake lead to Apple company lost many customer orders in 1999 (Tang., 2006). To response supply chain risk, there are lots of policies or strategy has been studied. Tang (2006) has reviewed 6 strategies (demand management, product management, supplier selection, robust management, information management, and order allocation) to process the supply chain interrupt. Neiger, Rotaru, and Churilov (2009) proposed a value-focused process engineering to reconcile the risk occurred in supply chain. Rajesh and Ravi (2015) propose a grey-DEMATEL method for modeling supply chain risk mitigation in electronic supply chains. Sawik (2016) shows that the shipping disruption risk in the service-oriented supply portfolio is more diversified than the cost-oriented portfolio, and the later will delay the expected supply, production and distribution schedules. Among those methods, the strategies proposed for improving supply chain performance is reported most in reducing loss or mitigating risk when supply chain meets the interrupt. However, as the studies conducted in risk-free supply chain coordination, the designing effective contracts to coordinate a supply chain in risk situation have been paid little attention. In this paper, we analyze some of contracts frequently mentioned in literature and used in practice, such as wholesale price contract, returns policy contract, also called buy-back contract, and revenue sharing contract, exploring, when the retailers are risk-averse, whether and how these contracts can be modified, to achieve supply chain coordination. Specifically, we investigate whether the some of these contracts can maximize the expected channel wide profit under retailer risk constraints. Or, if not coordinated, whether it can obtain a Pareto improvement, i.e. under the retailer downside risk constraint, the supply chain system or supply chain members' profit can be improved.

There are numerous studies on risk management in economics. Here we only focus on risk management issues in supply chain. A comprehensive literature review for supply chain risk can be found in the study of Tang (2006). An earlier paper that considered supply chain members risk is by Lau and Lau (1999). In Lau and Lau

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(1999) study, the measure of supply chain risk is evaluated by the mean-variance model. Under the newsvendor supply chain structure, Lau and Lau (1999) numerically show that the manufacturer's (here supplier) returns policy can benefit the manufacturer himself but hurt the retailer, i.e. the so-called anti-intuition. Whether the contract obtained Pareto improvement depends on the manufacturer's attitude towards risk. Under the same model structure as Lau and Lau (1999), but with price-dependent demand, Agrawal and Seshadri (2000a) adopt the increasing and concave utility function in profit to measure the supply chain member risk. They show how a risk-averse retailer chooses the order quantity and the selling price in a newsvendor inventory model. They consider two ways in which price affects distribution of demand; a change in standard deviation of distribution, and a change in only the mean value of distribution. They show that, in comparison to a risk-neutral retailer, a risk-averse retailer will charge a higher price and order less in the first case, while in case of the second scenario, he will charge a lower price. Based on this research, Agrawal and Seshadri (2000b) extended the model to the multi-retailers situation. The supplier (called intermediary) designs a contract menu to induce the retailer to choose a contract from the menu that maximizes the supplier's profits and simultaneously increases the retailer's order quantity. Tsay (2002) considers how risk-aversion affects both supplier and retailer under a Stackelberg game framework. Instead of using the expected profit, this study adopts the mean-variance objective function of profit to model the supply chain risk. Tsay (2002) showed that the behavior under risk-aversion is quite different from that under risk-neutrality and the penalty for errors in estimating a channel partner's risk-aversion can be substantial. He also derives conditions in which the supplier and the buyer prefer a full-return to a without return contract. Under the mean-variance measuring risk framework, Choi, Li, and Yan (2008) analyze the risk effect on the supply chain under a returns policy. They find that channel coordination is not always achievable under the risk controlled by mean-variance. This is sufficiently different with those most literature has reported that under ignoring risk aversions of the individual decision makers, channel coordination can always be achieved by setting a returns price. Choi and Chow (2008) also use the mean-variance analyze the quick response policies such as price commitment policy, service-level commitment policy, and buy-back policy and conclude that all these policy can obtain a win-win policy under some conditions. Chen and Federgruen (2000) use mean-variance to measure the risk in a number of basic inventory models. They exhibit how a systematic mean-variance trade-off analysis can be carried out efficiently, and how the resulting strategies differ from those obtained in the standard analyses. Chen, Sim, Simchi-Levi, and Sun (2007) derive the joint optimal inventory and pricing policy with Conditional Value-at-Risk (CVaR) measure to consider risk-aversion. Wang, Webster, and Suresh (2009) use exponential utility function to measure risk for studying the inventory risk. However, Chen and Federgruen (2000), Wang et al. (2009) and Chen et al. (2007) do not deal with full supply chain problems. Cachon (2004) analyzes an advance purchase contract in a newsvendor setting and discusses the impact of the contract on allocation of inventory risk. However, the "risk" in this paper refers to the expected cost of unsold inventory. No special risk measure is considered in either decision-maker's objectives, or in constraints. Based on the CVaR measure of risk management, Xu, Meng, and Shen (2013) proposes a tri-level programming model for the three-stage supply chain management. They transfer the tri-level programming model into a bi-level programming model and results show this method can be efficient for improving the risk management of the three-stage supply chain. There are also some qualitative methods for process supply chain risk. Under the Value-at-Risk (VaR) criterion and the Conditional Value-at-Risk (CVaR) criterion, Li, Hou, Chen, and Li (2016) formulate a dual channel supply chain consisting of a risk-neutral supplier and a risk-averse retailer, where the supplier as a Stackelberg leader, and obtain the equilibrium solutions in the decentralized and centralized situations. Liu, Cao, and Salifou (2016) studies a similar supply chain risk problem, but they use expected profit less than some tolerance to measure the risk and study the information value in risk supply chain. Kleindorfer and Saad (2005) propose a conceptual framework for disruption risk in supply chain management. Here the supply chain disruption risk refers to consequences of economic disruptions caused by natural disasters, strikes, and purposeful actions of agents, such as terrorists. This paper provides a conceptual framework that addresses risk assessment and risk mitigation, both of which are fundamental to disruption risk management in supply chains. However, this paper does not consider specific risk measures for evaluating supply chain coordination. Kumar and Tiwari (2013) incorporate risk pooling policy for both safety stock and running inventory into the location, production-distribution and inventory system to minimize the supply chain cost along with determining facility location and capacity. This policy can effectively mitigate the supply chain risk, but they are not used for coordinating supply chain management. Claypool, Norman, and Needy (2014) develop a Mixed Integer Programming (MIP) model to make the design for supply chain (DFSC) decisions while simultaneously considering time-to-market risk, supplier reliability risk and strategic exposure risk, and then use discrete event simulation to test the robustness of the MIP solution for supplier capacity risk and demand risk. Testing results show that risk mitigation strategies can partially solved from the DFSC and risk model. Downside risk as a financial risk measure has been widely used in financial-economic literature (Hu & Motwani, 2014; Markowitz, 1959; Szego, 2004; Ormos & Timotity, 2016; Reboredo, Rivera-Castro, & Ugolini, 2016; Shi, Qu, & Chu, 2016). For example, Ormos and Timotity (2016) introduce an equilibrium asset pricing model with the Expected Downside Risk (EDR) and they argue that the EDR is more realistic assumptions and so their model is able to describe equilibrium expected returns with higher accuracy. However, in supply chain risk study, little attention has been paid for researchers (Lorentz, Töyli, Solakivi, & Ojala, 2016). In the following paragraph, we review the Gan, Sethi, and Yan (2004, 2005) investigation in supply chain risk measurement with downside risk, in which it is most relevant with our study.

For the supply chain downside risk coordination strategy, Gan et al. (2004) analyzed coordinated contracts (actually Pareto-optimal contracts) with three kinds of risk measures: (1) downside risk to constrained the retailer, (2) mean-variance trade-off to measure the risk of both the supplier and the retailer, and (3) exponential utility function to measure the risk of the supplier and retailer. For the first case, they show that a wholesale contract can only reach a Pareto-optimal. For the second case, revenue sharing and buy-back contracts along with a side payment to the retailer can coordinate the supply chain under some conditions that satisfied the profit allocation proportion evaluated with risk measure. For the third case, they derive a similar conclusion as in the second case. Later, Gan et al. (2005) analyzed in detail the first case in Gan et al. (2004). Specifically, they first analyzed the natural downside risk (NDR) of the buy-back and revenue-sharing contract, where the NDR is defined as the expected target profit level under risk-neutral newsvendor as the downside risk-averse newsvendor. Then they showed that the NDR with buy-back or revenue-sharing contract cannot coordinate the supply chain. Therefore, they constructed a risk-sharing contract by which it can coordination the supply chain with the wholesale price limited condition under retailer downside risk constraint. It should be pointed out that above-mentioned analysis in Gan et al. (2004, 2005) is played with Nash game.