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# Manufacturer's return policy in a two-stage supply chain with two risk-averse retailers and random demand

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ABSTRACT

This paper studies the manufacturer's return policy and the retailers' decisions in a supply chain consisting of one manufacturer and two risk-averse retailers under a single-period setting with price-sensitive random demand. We characterize each retailer's risk-embedded objective via conditional value-at-risk, and construct manufacturer-Stackelberg games with and without horizontal price competition between the retailers. We explore, through numerical studies, the effects of the retailers' aversion to risk and other parameters on the manufacturer's return policy and profit and the retailers' decisions. We further investigate the effect of distribution asymmetry by comparing the results with normal and lognormal demand.


## 1. Introduction

This paper investigates the manufacturer's return policy in a two-stage supply chain consisting of one manufacturer and two risk-averse retailers in a single-period setting with price-sensitive random demand.[1] Differing from the previous studies that mainly focus on risk-neutral retailers, we examine risk-averse retailers with and without engaged in horizontal price competition, and how their attitudes towards risk affect the manufacturer's return policy and their decisions.

Return policies are an effective means to coordinate a decentralized supply chain when overstocking, resulting from demand uncertainties, incurs significant losses for downstream members (e.g. retailers). Return policies are often established between two stages in a supply chain. Recent advances on return policies for single-period products in a two-stage supply chain include (Bose and Anand, 2007; Emmons and Gilbert, 1998; He et al., 2006; Lau and Lau, 1999, 2002; Marvel and Peck, 1995; Padmanabhan and Png, 1997; Pasternack, 1985; Yao et al., 2008), focusing on one upstream member and one downstream member, and (Mantrala and Raman, 1999; Padmanabhan and Png, 1997; Yao et al., 2005), centered on one upstream member and multiple downstream members. Pasternack (1985), for instance, examined return policies in a supply chain with one manufacturer and one retailer, by utilizing a single period inventory model, and found that a pricing and return policy in which the manufacturer offers the retailer a partial credit for all unsold units can achieve channel coordination. In Pasternack's work, however, the distribution of demand is independent of the retail price. Emmons and Gilbert (1998) modeled a variation of the newsboy model in which demand is sensitive to retail price and takes on a multiplicative form, i.e. demand is the product of the expected demand, which is parameterized by the retail price, and a positive random variable. On the other hand, Lau and Lau (2002) and Yao et al. (2008) considered an additive model of demand, which is the sum of the expected demand and a random variable. Meanwhile, Bose and Anand (2007) studied and compared return policies with demand being independent of the retail price when the manufacturer's wholesale price is exogenous and endogenous.

In a decentralized chain with two downstream members, Padmanabhan and Png (1997) examined the manufacturer's return policy for two competing retailers with and without demand uncertainty. In their model, the manufacturer's return policy is restricted to either full returns or no returns, and retail demand is linear in price, with its primary demand taking on a fixed value under deterministic demand, and high and low values with certain probabilities under uncertain demand. Yao et al. (2005), on the other hand, examined the manufacturer's return policy in a newsboy model in which the random demand faced by two competing retailers is sensitive to retail price and takes on an additive form, as in Lau and Lau (2002). Mantrala and Raman (1999) investigated the supplier's return policy in a newsboy model with one retailer with two or more store outlets. In their model, these store outlets face random demand, but are not engaged in competition.

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[1] A preliminary version of the work was presented at the 3rd International Conference on Innovative Computing Information and Control in 2008.

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The aforementioned studies focused on a risk-neutral setting in which the chain members' objectives are to maximize expected profit. When facing random demand, however, the downstream members will be more concerned with the risk associated with demand uncertainties. This inclusion of risk into decision making has drawn a lot of attention in financial management (e.g. Alexander et al., 2006; Artzner et al., 1999; Duffie and Pan, 1997; Fishburn, 1997; Markowitz, 1952, 1959; Pflug, 2000; Rockafellar and Uryasev, 2000, 2002) and is gaining increasing interest in supply chain studies (Agrawal and Seshadri, 2000; Choi et al., 2008; Gan et al., 2005; Gotoh and Takano, 2007; Lau and Lau, 1988; Lau, 1980; Lau and Lau, 1999). Lau (1980) proposed two alternative objectives in a newsboy problem in which the optimum order quantity aims to maximize either expected utility or the probability of achieving a budgeted profit. Lau and Lau (1988) further extended this objective to a two-product newsboy problem.Extending Lau (1980), which considered only the retailer's aversion to risk, Lau and Lau (1999) examined both the manufacturer's and the retailer's aversion to risk in the framework of expected utility maximization. Agrawal and Seshadri (2000) examined a single-period supply chain with one risk-neutral vendor and multiple risk-averse retailers who aim to maximize expected utility, and found that a menu of mutually beneficial contracts offered by an additional intermediary to the retailers can eliminate the chain inefficiencies that arise due to the retailers' aversion to risk. Gan et al. (2005) investigated channel coordination in a newsboy model with a risk-neutral manufacturer and a risk-averse retailer. In their model, the risk-averse retailer determines the order quantity that maximizes the expected profit subject to the probability requirement of meeting a target profit level. Gotoh and Takano (2007) deployed the risk measure, conditional value-at-risk (CVaR), in a newsvendor problem with one risk-averse retailer, and discussed two types of loss functions based upon which CVaR minimization is sought to obtain the optimal order quantity. Choi et al. (2008) investigated the return policy in a supply chain with one supplier and one retailer, and due to the risk aversion in this supply chain, each decision maker maximizes the expected profit subject to a given requirement of the standard deviation of the profit. Chen et al. (2009) adopted CVaR to investigate the optimal policy of a risk-averse newsvendor who faces stochastic price-dependent demand, and established the sufficient conditions under which the optimal policy uniquely exists. Cheng et al. (2009) also considered CVaR as the retailer's objective in their proposed bilevel newsvendor models. Although all these studies examined risk aversion in a supply chain, they did not consider how the chain members' aversion to risk would influence their decisions, especially in a noncooperative setting where they are engaged in price competition. Consequently, the question of whether the effect of the chain members' aversion to risk is coupled with other parametric effects remains unanswered. This study intends to answer this question by analyzing the manufacturer's return policy in a noncooperative supply chain with one manufacturer and two risk-averse retailers on the basis of CVaR minimization, and in addition, explore the differences in the settings with and without horizontal competition. Thus, this study contributes to the current literature by providing insights on how risk aversion and other parameters affect the chain members' decisions in a noncooperative supply chain.

CVaR is a commonly used coherent risk measure (Pflug, 2000), and is more tangible to assess, as compared with utility-based measures. In addition, the computational complexity in CVaR minimization has been alleviated by the introduction of the transformation function of the CVaR by Rockafellar and Uryasev (2000). To the best of our knowledge, Gotoh and Takano (2007) first employed CVaR minimization in a newsboy problem with a risk-averse retailer. This study also adopts CVaR minimization, but differs from Gotoh and Takano (2007) in that the manufacturer plays an important role in the supply chain and acts as a Stackelberg leader to determine the return policy.[2] Further, it allows for two scenarios of horizontal interaction between the risk-averse retailers, that they are and are not engaged in horizontal price competition.

Based on CVaR minimization, we establish the net-loss and the total-cost measures to evaluate the retailers' losses, in line with Gotoh and Takano (2007), when the retailers are not engaged in horizontal price competition, and use the net-loss measure when they are engaged in it. Through numerical analysis, we aim to explore how the retailers' aversion to risk will affect the manufacturer's unit return price and profit, and the retailers' decisions under different measures and settings. What will happen to the results if risk aversion and another parameter are altered, while keeping the other parameters fixed? Will demand distribution have an impact on the chain members' decisions? The remainder of the paper is organized as follows. The next section details the manufacturer-Stackelberg game in a two-stage supply chain with one manufacturer and two retailers in the absence and the presence of horizontal price competition. Section 3 constructs the retailers' risk-embedded formulations via conditional value-at-risk, analyzes the structural properties of these formulations, and delineates the procedure of finding the equilibrium in the manufacturer-Stackelberg game. Section 4 demonstrates, through numerical studies, the effect of certain parameters on the manufacturer's return policy and profit and the retailers' decisions under two measures. Finally, Section 5 concludes with a brief summary of this work, along with some suggestions for future research.

## 2. Framework

We consider a pricing and ordering game in a two-stage supply chain in which one manufacturer sells his short-life-cycle products through two retailers under price-sensitive random demand. In this game, the manufacturer acts as a Stackelberg leader and determines his decision, the unit return price $s$, before the retailers make their decisions. The retailers' decisions depend on whether or not they are engaged in horizontal price competition. In the scenario that the retailers are engaged in such competition, each retailer $i$'s ($i = 1, 2$) decision consists of the selling price $p_i$ to the market and the order quantity $q_i$ to be placed on the manufacturer. On the other hand, in the scenario that the retailers are not engaged in horizontal price competition, the retailers' unit selling prices are considered to be exogenous and identical, i.e. $p_1 = p_2 = p$, where $p$ denotes the market price, and each retailer's decision is simply the order quantity $q_i$. This study examines both scenarios and models the random demand faced by each retailer in both scenarios to take on an additive form. Specifically, $X_i = D_i + \epsilon$ denotes the random demand faced by retailer $i$ in the presence of horizontal price competition, where $D_i$ is the expected demand of retailer $i$:

$$D_i = a - bp_i + \gamma p_j, \quad i = 1, 2 \quad \text{and } j = 3 - i \tag{1}$$

and $\epsilon$ is the random noise with CDF $G(\cdot)$, mean $E[\epsilon] = 0$, and standard deviation $\sigma > 0$. In the expected demand function in (1), $a > 0$ represents the primary demand, $b$ the store-level factor (Padmanabhan and Png, 1997; Yao et al., 2005), and $\gamma$ the competition factor. We assume $b > \gamma$ so that the change of $p_i$ is more influential to retailer $i$'s expected demand than that of the rival's unit selling price $p_j$, $j \neq i$. The form of the random demand $X_i$ is typical in the literature concerning competition between the retailers (Padmanabhan and Png, 1997). In the absence of horizontal price competition between the retailers, we let $\widetilde{X}_i = \widetilde{D}_i + \epsilon$ denote the random demand faced by retailer $i$, where $\widetilde{D}_i$ is the expected demand of retailer $i$

[2] In a Stackelberg game, the players move sequentially and the player who moves first is the leader. A Stackelberg game with the manufacturer acting as the leader is then referred to as a manufacturer-Stackelberg game.