Analyzing Consumer Returns Policy in a Dual-channel Supply Chain with a Risk-averse Retailer

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Abstract: This paper investigates a dual-channel supply chain consisting of a risk-neutral manufacturer and a risk-averse retailer. The manufacturer offers a consumer returns policy in the online channel, in which consumers face valuation uncertainty. We use conditional value-at-risk (CVaR) criterion to evaluate the risk-averse behaviour of the retailer. We examine how consumer returns policy and risk-averse behaviour influence the equilibrium solutions and supply chain agents' performance. It is shown that the manufacturer's optimal returns policy is related to consumer types. If the consumer has a moderate valuation of the product, the optimal returns policy depend on the retailer's risk-averse level. We observe a counter-intuitive phenomenon, the retailer's expected utility may increase under the double pressure of manufacturer encroachment and better returns service. Furthermore, a buyback revenue-sharing contract is offered to coordinate the dual-channel supply chain when the refund is endogenous. Finally, we explore several extensions.

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1 Introduction

New commercial patterns and opportunities are being created in the ear of e-commerce. Manufacturers can open direct channels (e.g. online stores or catalog sales) apart from the traditional reselling channels. This causes competition between the manufacturers and the resellers, a phenomenon called "manufacturer encroachment" (Arya et al., 2007; Li and Gilbert et al., 2014). For example, Estée Lauder and Johnson & Johnson in cosmetics industry, Samsung and Sony in electronics industry and Nike, Adidas and Levi Strauss and Co. (Levi's) in fashion industry etc., they all have their own direct channels and traditional reselling channels (Xiong et al., 2012; Hsiao and Chen, 2013; Moon and Yao, 2013). Introducing a direct channel can help firms increase market size, obtain more direct feedbacks from consumers, boost the total supply chain profits and mitigate double marginalization (Chiang et al., 2003; Li and Gilbert et al., 2015). Simultaneously，e-commerce also changes consumer purchasing behaviour. Under Internet transactions, consumers can easily shopping through various websites. Transactions are no longer constrained by time and distance. However, some psychological factors raise consumers' concerns about online shopping since consumers are unable to see and inspect the products before making their purchases (Hsiao and Chen, 2012). Further, although online descriptions by images or videos can help consumers learn about the products, online shopping is lack of emotional experiences and directing instructions, or the goods may be lost or damaged during the delivery. Therefore, opening a direct channel, on one hand, strengthens the competitiveness of manufacturers; on the other hand, it also brings about additional challenges in customer services. One of the top concerns of online shopping is the difficulty in returning unsatisfactory purchases (Lee, 2002). Generally, more returns happen in the online channel than in the traditional channel (Rao et al., 2014).

In response to the purchasing uncertainty of online products, the manufacturers often offer a variety of returns policies to alleviate consumers' psychological burden. In practice, two major electronic products manufacturers, Samsung Electronics (http://www.samsung.com/cn/home) and Apple Inc. (http://store.apple.com/cn) promise returns policies for their online sales. Another example in the cosmetics industry such as Dabao, a sub-brand of Johnson & Johnson Company (http://dabao.tmall.com), promises a generous "no questions asked" money-back guarantee for consumers. It has been demonstrated that more than 70 percent of consumers would consider returns policies before their purchasing (Trager, 2000). Therefore, returns service not only can enhance firm's competitiveness (Sullivan, 2009), but also can increase consumers' confidence in the product quality. Obviously, providing a consumer returns policy is a useful mechanism for the sellers (Wood, 2001). Further, according to Suwelack et al. (2011), returns policies stimulate market demand and positively impact consumers' willingness to pay. However, the negative implications of the returns policy cannot be ignored. Too liberal returns policies often give rise to excessive amount of consumer returns and inventory. In addition, dealing with returned products consumes manufacturers' massive time and increases reverse logistics cost. Therefore, how to design an optimal returns policy is very important for manufacturers.

Manufacturer encroachment has a significant impact on the retailers (resellers) in the traditional channel (Collinger, 1998; Machlis, 1998; Tsay and Agrawal, 2004; Arya et al., 2007; Li and Gilbert et al., 2014, 2015). Retailers believe that cannibalization effect is bound to happen in the dual-channel supply chain. The manufacturers not only carve up the market by establishing their direct channels, but also offer the returns policy to offset the weakness of the online shopping. These factors may lead to a higher degree of uncertainty and greater competitive pressure for retailers. Especially, when the market demand is uncertain, the retailers tend to behave in a risk-averse way (Choi et al., 2008). Thus, it is of great importance to incorporate the retailers' risk aversion into the decision framework in the manufacturer encroachment situation.

However, to the best of our knowledge, little research has been published on the optimal decisions in the manufacturer encroachment situations simultaneously considering the manufacturer's returns policy and the retailer' risk-averse behaviour. This paper attempts to fill this research gap. More specifically, we consider a dual-channel supply chain with a risk-neutral manufacturer and a risk-averse retailer, in which the manufacturer produces a single type of products and sells them via his own online channel and the traditional retail channel, and offers consumers a returns policy for his online channel. We will examine the following issues: how would a risk-averse retailer make her optimal order decisions in response to the manufacturer's different returns policies for its online channel? How will the combinational factors of the manufacturer's different return policies and the retailer's risk-averse attitude influence their decisions and performance? What is the manufacturer's optimal returns policy facing heterogeneous consumers? How to coordinate the dual-channel supply chain in the presence of consumer returns and a risk-averse retailer? Does the returns policy play an important role in improving the competitiveness of the online channel? Does providing the returns policy always hurt the retailer's utility? To answer these questions, we evaluate the retailer's risk level using conditional value-at-risk (CVaR) criterion, which is widely applied in the field of finance and economic literature (Alexander and Baptista, 2004; Zhu and Fukushima, 2009). In addition, the market demand is uncertain and refund-amount related (Xiao et al., 2010; Liu et al., 2014). The objective of the retailer is to maximize her expected utility and the objective of the manufacturer is to maximize his expected profit.

The rest of this article is organized as follows. The relevant literature is reviewed in Section 2. Section 3 describes the parameters notation and each agent's objective functions. In Section 4, we first model the dual-channel supply chain when the refund amount is exogenous and study the impacts of the consumer returns policy and the retailer's risk attitude on agents' decisions and performance. Then we study the situation when the refund amount is endogenous. In Section 5, we design a contract to coordinate the dual-channel supply chain with endogenous refund amount. Followed by Section 5, Section 6 uses numerical examples to reveal two important impacts of returns policy. Section 7 describes several model extensions. Section 8 summarizes the results and suggests several possible future work.

2 Literature review

The relevant literature can be divided into two streams: the first concerns with optimal decisions of the consumer returns policy in supply chains; the second is related to modelling the risk-averse behaviour of agents in supply chains.

There is rich literature related to the optimal decisions of the consumer returns policy in supply chains. For example, Hsiao and Chen (2012) considered a two-echelon supply chain with an Internet seller and heterogeneous consumers. In response to the product quality uncertainty, Internet seller offered returns policies. They characterized the optimal returns policies and pricing strategy under an exogenous quality, and showed all inappropriate returns could be eliminated by carefully designed returns policies. Chen and Bell (2012) proposed a dual-channel structure including a returnable channel and a nonreturnable channel. The impact of different returns policies on the optimal decisions and profit was investigated in such a structure. Sun et al. (2013) studied a multi-period acquisition pricing and remanufacturing decision problem. Products returned in their paper were assumed price-sensitive. They acquired the solution structure of the optimal remanufacturing quantity and derived a monotonic pricing policy. Chen and Grewal (2013) studied the optimal returns policy with two competing retailers (a well-established retailer and a new entrant). The Stackelberg game was adopted to determine whether the new entrant retailer should implement a full-refund policy or a no-refund policy. Ren et al. (2014) studied a dual-channel supply chain with price and service competition involving consumer returns policies. They analysed the optimal pricing decisions in both centralized and decentralized scenarios, and designed a new contract to coordinate the dual-channel supply chain. Ruiz-Benitez and Muriel (2014) considered a supply chain consisting of a manufacturer and a retailer facing stochastic demand. Two returns policies, full refund and no return, were compared in terms of the optimal wholesale price, ordering quantities and profits. They proved that "double marginalization" effect was milder under the full-refund policy. Huang and Yang (2015) considered a contract design problem when the retailer provided a full returns policy. They derived the optimal menu of contracts and investigated the impact of the retailer's market value on the supply chain performance. Although a lot of researches studied about consumer returns policy, the majority of them focused on a single channel supply chain. In our paper, we will develop a Stackelberg game of a dual-channel supply chain and analyse the equilibrium solutions with a parameterized refund amount.

When the manufacturers open their direct channels, the channel competition will bring much more pressure on the traditional retailers and then they may have risk-averse behaviour. Risk aversion is a common concept in economics and finance, which can be measured using Mean-Variance (MV) approach (Markowitz, 1959), Value-at-Risk (VaR) and Conditional Value-at-Risk (CVaR) (Rockafellar and Uryasev, 2002; Alexander et al., 2004). From the late 1990s, the risk-aversion concept has been introduced into supply chain management. Lau and Lau (1999) analysed a buyback issue in a supply chain consisting of a manufacturer and a retailer, and each agent had a mean-variance objective function. Gan et al. (2005) used VaR method to study channel coordination with a risk-neutral manufacturer and a risk-averse retailer. They found that a risk-sharing contract could transfer the retailer's risk and coordinate the entire supply chain. Ma et al. (2012) considered a risk-neutral manufacturer and a risk-averse retailer in a Nash bargaining game. They adopted CVaR criterion and showed how bargaining power and risk-averse level influenced agents' decisions. Li and Chen et al. (2014) investigated a dual-channel supply chain in which the risk-neutral manufacturer with a direct channel produced one perishable product and the risk-averse retailer faced a price dependent stochastic demand. CVaR method was applied to gauge the retailer's risk-averse level and a Nash bargaining problem was built to analyse the decisions of agents.

In terms of the consumer returns issues in supply chain management, there are a limited number of papers considering the agents' risk behaviour. Liu et al. (2012) formulated an analytical model with both demand and consumer return uncertainties and solved the optimal price, consumer return, and level of modularity for a mass customization (MC) manufacturer. The MC manufacturer sold MC products directly to consumers. They used the mean-variance (MV) method to measure the MC manufacturer' risk aversion level. They found that the optimal decisions on retail price, refund rate, and modularity level were decreasing in the degree of manufacturer's risk aversion. Choi et al. (2013) explored consumer full returns policy and no return policy under fashion MC program. By modelling the optimization objective of the risk averse MC fashion brand using the mean-variance method, they derived the closed-form of the optimal solution under either returns policy. Liu and He (2013) examined the optimal decisions in a two-echelon supply chain facing uncertain demand and uncertain consumer returns. They used the MV objective framework to measure the decision-makers' risk preference. The results showed that only buyback contract could coordinate the supply chain when the agents were risk-neutral or risk-averse. Yoo (2014) applied a mean-risk model to measure the manufacturer's risk. The aim was to study the quality-related consumer returns issue where the buyer in the supply chain decided the optimal returns policy for consumers and the upstream manufacturer made the production quality decision. Because MV equally evaluates desirable upside outcomes and undesirable downside outcomes, and VaR is an incoherent risk measure (Ma et al., 2012), CVaR method was proposed to overcome the weakness of MV and VaR and has been applied in many industries. However, there are few researches to measure the risk-averse behaviour in supply chain management through CVaR method, especially in dual-channel supply chain. This paper will complement the literature by adopting the CVaR method to measure the retailer's risk-averse behaviour in a dual-channel supply chain. Further, we analyse the optimal decisions under the online consumer returns policy and the impacts of the risk-averse indicator on the optimal decisions.

This paper investigates agents' optimal decisions in dual-channel supply chains where the online channel provides consumer returns policies. We also consider the retailer's risk aversion using the CVaR criterion. The differences of this paper from the literature can be explained as follows. We consider the consumer returns policy in a dual-channel supply chain, which explicitly models the conflict relationship between supply chain members and the competition relationship between two channels; whereas the majority of literature about returns policy concentrated on a single channel. In those limited number of studies on consumer returns policy in supply chain management, they either assume that the supply chain members are completely rational or evaluate the agents' risk-aversion using MV method (Liu and He, 2013; Yoo, 2014). In this paper we use CVaR measure, which is consistent with agents' normal psychological reactions to risk because it reflects the downside-risk level. By using CVaR criterion, we are able to evaluate the impact of the retailer's worst-case risk behaviour in the presence of manufacturer encroachment with consumer returns policy. To have a clearer view of how our work differs from the previous relevant studies, we compare our paper with the aforementioned literature on consumer returns in supply chain in Table 1. These papers are compared mainly in five aspects. The first column in Table 1 represents whether the paper considers consumer returns policy in online channel and/or offline channel and FR, PR, NR denote full returns, partial returns and no return respectively. The second column represents the channel structure studied in each paper (e.g. one echelon or two echelon). The rest three columns show that whether the paper considers supply chain members' risk behaviour, who has risk-averse or risk-seeking attitude and the methods used to measure the risk attitude.

Table 1 Summary of the literature review (consumer returns in supply chain)

Reference	On / Off	CS	Risk Preference	Member	Method
Su (2009)	-/ FR,PR	T	N		
Xiao et al. (2010)	-/FR,NR	T	N		
Liu and Choi et al. (2012)	-/PR	O	N, A	Seller	MV
Chen and Bell (2012)	-/FR,NR	O	N		
Hsiao and Chen (2012)	FR,PR,NR/-	O	N		
Chen and Grewal (2013)	-/FR,NR	T	N		
Li et al. (2013)	FR,PR,NR/-	O	N		
Liu and He (2013)	-/FR	T	A, S	Manufacturer and retailer	MV
Choi et al. (2013)	-/FR,NR	O	A	Seller	MV
Ren et al. (2014)	FR / FR	T	N		
Li and Xu et al. (2014)	-/ FR,PR	O	N		
Ruiz-Benitez and Muriel (2104)	-/ FR,NR	T	N		
Yoo (2014)	-/FR,NR	T	N&A	Supplier	MV
Liu et al. (2014)	-/PR	T	N		

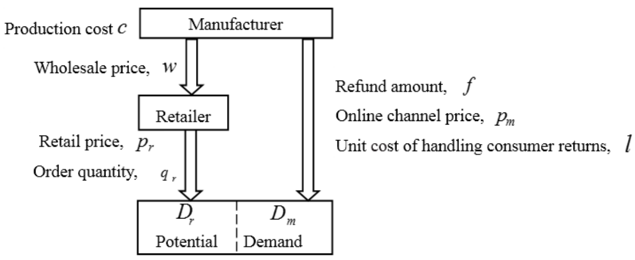
Huang and Yang (2015)	-/FR	T	N		
Our paper	FR,PR,NR/NR	T	N&A	Retailer	CVaR

Note. T represents two echelon, O represents echelon in the column Channel Structure. N represents neutral, A represents risk-averse and S is for risk-seeking in the column Risk Preference.

3 Model description

We consider a dual-channel supply chain consisting of a risk-neutral manufacturer (he) and a risk-averse retailer (she). At the beginning of the sales season, the manufacturer produces a single type of products at unit cost c and operates his own online channel with a consumer returns policy. A make-to-order policy is adopted in the online channel, while the retailer places an order to the manufacturer before the sales, this is because the demand in the retail channel is relatively stable and predictable. Such mixed strategy of make-to-order and make-to-stock is supported by Adan and Wal (1998), Carr and Duenyas (2000) and Li and Chen et al. (2014). We assume the manufacturer is a Stackelberg leader, that is, the manufacturer decides his wholesale price in the first move. Then the retailer, as a follower, makes her order decision after observing the manufacturer's choice. The channel structure is shown in the Figure 1. In Section 7, we will extend the model to incorporate both agents' pricing strategies.

Figure 1 Dual-channel supply chain structure



The selling prices in the retail channel and in the online channel are p_r and p_m respectively. Some studies assume the consistent pricing, i.e. $p_r = p_m$, e.g. strategy is considered in previous papers such as Cattani et al. (2006), Cai et al. (2009) and Wen et al. (2013), they assumed that the manufacturer committed to adopt the same price on the online channel and the retail channel. However, the inconsistent pricing, i.e.. $p_r \neq p_m$., is more practical. Several market surveys have found that online prices are usually lower than offline prices within a certain range of 4-16% for the reasons such as lower barriers to entry the market and lower operational costs of online channel (e.g. Brynjolfsson and Smith, 2000; Tang and Xing, 2001; Lo et al., 2013; Bhatnagar and Syam, 2014). Taking into account the above observations, we assume that the online price is not greater than the retail price, but not less than the average of the production cost and the retail price (i.e. $(p_r + c)/2 < p_m \leq p_r$). Here the assumption $(p_r + c)/2 < p_m$ is for the simplicity of analysis in the following, but also reflects the observation that the online price is within a reasonable range of the offline price p_r. We assume that the manufacturer offers a consumer returns policy to the online channel, but the retailer does not offer a return policy to the offline consumers. The former can be understood as the manufacturer's customer service to overcome the disadvantage that consumers in the online channel are difficult to judge the fitness of the product without physically observing and trying it. The latter may be justified as follows. For the bricks-and-mortar stores, the retailer has displayed proper samples of various product models on the shelves, and/or hired highly qualified sales people, so the consumers can be ensured to find the right product before committing the purchase. In addition, consumers are able to inspect and try-out the product in the retail store, which can further decrease the likelihood of a mismatch. Therefore we assume that only the online channel provides the consumer returns service in this paper. The returns policy is parameterized by a policy parameter f and f represents the refund amount. If $f = 0$, it means no return is allowed. If $f = p_m$, it represents full refunds (or full returns). Besides, the refund amount between zero and the selling price implies that the manufacturer offers partial refunds (or partial returns) to consumers. For simplicity, we will first assume the refund amount as an exogenous factor similar to Xiao et al., (2010) and Liu et al., (2014). Later on we will treat the refund amount f as an endogenous decision variable. Much literature has shown that the amount of returned products has a strong positive relation with the refund amount (Xiao et al., 2010; Liu et al., 2014). In our model, consumers face valuation uncertainty in the manufacturer's online channel. At first, consumers attempt to purchase the products and their valuations are only realized after purchase (Su, 2009). So in the online channel, we assume that consumer valuation V is an independent and identically distributed random variable with distribution $G(\cdot)$. These realizations are not known until the consumer receives the product. A consumer's surplus of keeping the product bought online is $v - p_m$, and the surplus of returning this product is $f - p_m$. A consumer with post-purchase valuation v will return the product if and only if $v - p_m \le f - p_m$. Thus probability of consumer returns is $G(f) = prob(v \le f)$.

Shulman et al. (2010) mentioned that 95% of the consumer returns belonged to nondefective products that were not what the consumer was expecting (false failure returns). For the nondefective returns, timely disposition such as refurbish, repackaging and reshelf becomes paramount rather than remanufacture (Crocker and Letizia, 2014). Therefore, we assume that the returned products from consumers cannot be resold within this selling period due to the need for inspection, repackaging, and reshelving (Chen and Bell, 2012). All leftover products are salvaged at prices s. Meanwhile, the manufacturer incurs a cost l related to handling the returned products including verifying purchase, repackaging, reshelving and carrying cost during the return processes. In Section 7, we will extend this assumption to consider that the returned products are remanufactured by the manufacturer and the cost structure is also changed.

The notations and the parameters are defined as follows:

i $\quad i = r, m$, where r denotes the retail channel and m denotes the manufacturer's online channel;

w $\quad$ the wholesale price, a decision variable of the manufacturer. We assume $w \le p_m$, otherwise the retail channel becomes meaningless since she would prefer to buy products from the online channel;

q_r the order quantity in the retail channel, a decision variable of the retailer;

θ the degree of consumer loyalty to the retail channel, i.e. $1-\theta$ represents the degree of consumer loyalty to the online channel, and $0<\theta<1$;

c the production cost per unit and $c<w$;

s the salvage value per unit for the returned and leftover product, here we assume $s<c$;

V a random variable which represents the consumer's post-purchase valuation with an increasing distribution $G(\cdot)$;

f the refund amount in the online channel with $0 \le f \le p_m$;

l the unit cost of handling consumer returns undertaken by the manufacturer, to make the return meaningful, we assume that $l \le s$ otherwise the manufacturer won't recycling returned products;

ρ_i the returns sensitivity parameter, it represents the demand's sensitivity to the returns policy in each channel, here assume the returns policy's effect on the online channel is greater than it on the retail channel by $0<\rho_r<\rho_m$ (Li et al., 2013).

The total market demand is stochastic, which can be described as: $\bar{D}=D+\xi$, where D is the basic product demand and ξ is a random variable that suggests the market demand uncertainty following a uniform distribution on $[-U,U]$ with $D \ge U \ge 0$, $\phi(\cdot)$, $\Phi(\cdot)$ are the density and the cumulative function of ξ respectively. Following Hua et al. (2010), Dan et al. (2012) and Lu and Liu (2013), we also assume that the demand functions are linear in the prices and the refund amount. The prices are assumed exogenous in the basic model and this assumption will be relaxed in Section 7. Demand functions are formulated as follows:

$$D_r=\theta\bar{D}-p_r+\alpha p_m-\rho_r f \tag{1}$$

$$D_m=(1-\theta)\bar{D}-p_m+\alpha p_r+\rho_m f \tag{2}$$

The parameter α is the cross-price sensitivity with $0<\alpha<1$. ρ_i represents the intensity of competition between the two channels with regards to f. Note that return compensation can stimulate consumer demand and correspondingly increase sales (Li et al., 2013), if the refund amount increases by one unit, ρ_m units of the demand will increase in the online channel, meanwhile ρ_r units of the demand will be lost in the retail channel.

The manufacturer's profit is:

$$\pi_m=(w-c)\cdot q_r+(p_m-c)\cdot\bar{G}(f)D_m+(p_m-c-f+s-l)\cdot G(f)D_m \tag{3}$$

In Equation (3), the first term corresponds to the revenue sold to the retailer, the second term comes from the products sold at his direct channel and not returned by consumers, and the third term represents the salvaging revenue from products that are bought but returned by the consumer in the online direct channel. It should be noted that the third term could be negative. The retailer's profit is given as follows:

$$\pi_r=p_r\cdot min(q_r,D_r)-w\cdot q_r+s[q_r-D_r]^+ \tag{4}$$

In Equation (4), the first term corresponds to the retailer's sales revenue, the second term represents the money paid to the manufacturer and the third term represents the salvage value of the leftover products if there are any.

Denote $(\cdot)^+ = \max(\cdot, 0)$. We apply CVaR criterion to evaluate the risk-averse behaviour of the retailer. When the retailer places an order quantity q_r to the manufacturer, her utility under η -CVaR criterion is defined as follows (Rockafellar and Uryasev, 2000):

$$CVaR^{\eta}(\pi_r) = \max_{\mu \in R} \left\{ \mu + \frac{1}{\eta} E\left[\min\left(\pi_r - \mu, 0 \right) \right] \right\}$$

Where η denotes a risk-averse indicator of the retailer and μ represents her target profit level $z_{\eta}(\pi_r(q_r))$ based on the VaR measurement. $z_{\eta}(\pi(q_r))$ is also the η -quantile of $\pi_r(q_r)$ and defined as follows: $z_{\eta}(\pi(q_r)) = \inf\{v | \Pr(\pi(q_r) \le v) \ge (1-\eta)\}$. When $\eta = 1$, the retailer is risk-neutral and when η tends to 0, the retailer becomes more risk-averse. As CVaR is a continuous risk measure, we obtain the following equivalent functions to denote the retailer's utility under η -CVaR criterion:

$$CVaR^{\eta}(\pi_r) = \begin{cases} (p_r - w)q_r - \dfrac{(p_r - s)\theta}{\eta} \displaystyle\int_{-U}^{\frac{q_r - \alpha p_m + p_r + \rho_r f}{\theta} - D} \Phi(\xi) d\xi, & q_r \le \theta D - \rho_r f + \alpha p_m - p_r + \theta \Phi^{-1}(\eta) \\ (p_r - s)\theta \Phi^{-1}(\eta) - (w - s)q_r + (p_r - s)[\theta D - \rho_r f + \alpha p_m - p_r] - \dfrac{(p_r - s)\theta}{\eta} \displaystyle\int_{-U}^{\Phi^{-1}(\eta)} \Phi(\xi) d\xi, & q_r > \theta D - \rho_r f + \alpha p_m - p_r + \theta \Phi^{-1}(\eta) \end{cases} \tag{5}$$

The retailer's utility function as well as the above inference process are provided in the Appendix 1.

4 Model analysis

In this section, we consider the case of exogenous prices. First the equilibrium results are derived, and the sensitivity analyses of equilibrium results are provided in Section 4.1. Impacts of the consumer returns policy and the risk-averse indicator on two agents in the supply chain are given in the Section 4.2.

4.1 Equilibrium Analysis

In the Stackelberg game, the manufacturer first decides the wholesale price, then the retailer decides the order quantity. According to Equation (5), we have:

（1） If $q_r > \theta D + \alpha p_m - p_r - \rho_r f + \theta \Phi^{-1}(\eta)$, then $\dfrac{\partial CVaR^{\eta}(\pi_r)}{\partial q_r} = -(w - s) < 0$.

So $q_r^* = \theta D + \alpha p_m - p_r - \rho_r f + \theta \Phi^{-1}(\eta)$. Note that this case is the boundary of the feasible regions, the solution is included in the other case, so the paper just focuses on the following situation.

（2） If $q_r \le \theta D + \alpha p_m - p_r - \rho_r f + \theta \Phi^{-1}(\eta)$, then

$$CVaR^{\eta}(\pi_r) = (p_r - w)q_r - \frac{(p_r - s)[q_r - \alpha p_m + p_r + \rho_r f - \theta D + U\theta]^2}{4U\eta\theta} \tag{6}$$

The manufacturer's expected profit is as follows:

$$E(\pi_m) = (w-c)\cdot q_r + [p_m - c - G(f)\cdot(f-s+l)]\cdot[(1-\theta)D + \alpha p_r - p_m + \rho_m f] \quad (7)$$

Using standard backward induction, we obtain the equilibrium solution (q_r^* , w^*) as follows:

$$q_r^* = \frac{1}{2}[(D-U)\theta - \rho_r f + \alpha p_m - p_r] + \frac{U\eta\theta(p_r - c)}{p_r - s} \quad (8)$$

$$w^* = \frac{p_r - s}{4U\eta\theta}[(D-U)\theta - \rho_r f + \alpha p_m - p_r] + \frac{p_r + c}{2} \quad (9)$$

Some conditions are required to ensure the system is physically meaningful. First, to keep the dual-channel supply chain structure feasible, both channels' demands must be non-negative. Second, $w^* \le p_m$. Accordingly, we obtain the following constraints:

$$p_m \le p_r < \min[(D-U)\theta + (\alpha - \rho_r)p_m, (2p_m - c)] \text{ and } \eta \in [\underline{\eta}, 1],$$

$$\text{where } \underline{\eta} = \frac{(D-U)\theta + \alpha p_m - p_r}{2U\theta} \cdot \frac{p_r - s}{2p_m - p_r - c}.$$

To examine the impacts of the refund amount and the risk-averse indicator on the decision variables, we obtain the following results:

Proposition 4.1: Under the conditions $\eta \in [\underline{\eta}, 1]$, there are some properties of the equilibrium solutions as follows:

$$\frac{\partial q_r^*}{\partial f} < 0,\ \frac{\partial w^*}{\partial f} < 0;\ \frac{\partial q_r^*}{\partial \eta} > 0,\ \frac{\partial w^*}{\partial \eta} < 0;\ \frac{\partial w^*}{\partial \theta} > 0,\ \frac{\partial q_r^*}{\partial \theta} > 0.$$

The proof is given in Appendix 2[1]. In Proposition 4.1, the first group reveals that the retailer's order quantity is decreasing in f . This is intuitive because the demand in the online channel becomes larger as f increases; and this brings about more intense competition between two channels. Facing with a shrinking market, the retailer reduces her order quantity to avoid too many leftovers. As for the manufacturer, a larger refund amount f will decrease its profit from the online channel and break the equilibrium between two channels. This would lead to his willingness to charge a lower wholesale price to stimulate a higher order quantity from the retailer. In other words, as f increases, the manufacturer tends to shift more order quantity towards the retailer channel by lowering the wholesale price. For the influences of the risk-averse indicator η , the retailer is decreasing her order quantity when η tends to 0 (i.e. becomes more risk-averse). On the contrary, the manufacturer will decrease his wholesale price and transfer his cooperative willingness to the retailer when the retailer becomes less risk-averse.

The third group in Proposition 4.1 indicates that the wholesale price and the order quantity increase in θ . When θ is small, the basic demand in the retail channel is low. So too many order quantity may give rise to excessive leftovers. However, as θ increases,

[1] All the appendixes are provide online

the basic demand in the retail channel becomes larger. The retailer bears less risk in overstocking. Her order quantity is responsive to the increase in θ. As regards the effect of θ on the wholesale price, when θ is small, the manufacturer can earn considerable profit in his online channel. Then, he is willing to set a lower wholesale price to encourage the retailer to order more. As θ increases, the manufacturer knows that the retailer is bound to increase her order quantity. Motivated by this, the manufacturer increases the wholesale price to make more money.

4.2 Impacts of the returns policy and the risk-averse indicator on agents' performance

In this section, we discuss the impacts of the refund amount f and the retailer's risk-averse indictor η on two agents' performance. First, we examine how the refund amount influences the retailer's expected utility.

Proposition 4.2: （1）For the fixed refund amount f, the retailer's expected utility is monotonically increasing as her risk-averse indicator η increases. The risk-neutral retailer will gain the most expected utility. （2）For the fixed risk-averse indicator η, there exists a threshold $f_r = \dfrac{(D-U)\theta + \alpha p_m - p_r}{\rho_r} - \dfrac{2U\eta\theta}{3\rho_r} \cdot \dfrac{p_r - s}{p_r - c}$ such that:

i) if $f_r < 0$, then the retailer's expected utility is monotonically decreasing in f.

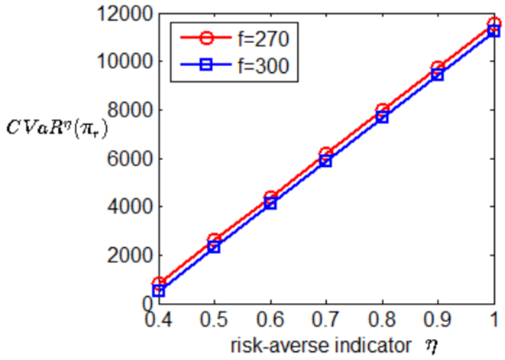
ii) if $0 \le f_r < p_m$, then the retailer will achieve the maximum expected utility when $f = f_r$.

iii)if $f_r \ge p_m$, then the retailer's expected utility is monotonically increasing in f.

The proof is given in Appendix 3. As the retailer's risk-averse indicator η increases (towards less risk-aversion), the retailer's expected utility is increasing. This result highlights an important conclusion that the retailer could achieve the highest expected utility if she is risk-neural. Proposition 4.2 (2) indicates that at a given risk-averse level of the retailer, the relationship between the retailer's expected utility and the manufacturer's refund amount can be characterized by a single threshold value f_r. Here f_r can be interpreted as a parameter that is associated with the market environment such as base demand, degree of consumer loyalty, etc. In particular, when $f_r > p_m$, the retailer's expected utility will monotonically increase in f for any $f \le f_r$. This is a counter-intuitive phenomenon, because: (i) manufacturer encroachment arouses channel competition between the retailer and the manufacturer; (ii) the manufacturer is enhancing the return service in his online channel to attract more consumers, which should intensify the competition between two channels. We explain this surprising phenomenon from two aspects. On one hand, larger degree of consumer loyalty to the retail channel and higher basic market demand ensure higher market demand sharing for the retailer. This will decrease retailer's risk of ordering. On the other hand, because the wholesale price will decrease as the increase of f. The manufacturer would like to compensate the retailer by reducing the wholesale price when he raises the refund amount in his direct channel. When the basic market demand is relatively low, i.e. $f_r < 0$, the retailer will face higher risk of ordering. At the same time, higher refund amount will also bring huge damage to retailer's basic market sharing. Therefore, the retailer's expected utility is decreasing in f. When market demand is moderate, i.e. $0 \le f_r < p_m$, the retailer's expected utility is first increasing then decreasing in f. There is enough market demand when the refund amount keeps in a low level, thus retailer's expected utility is first increasing in f. When f gradually increases, retailer's market demand share shrinks, thus retailer's expected utility starts decreasing.

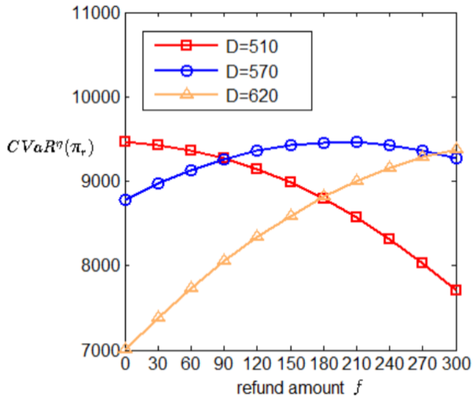
The following numerical experiments are used to verify the results. In our experiments, most parameters are set up based on the literature. For example, θ and α are set up based on Li and Chen et al. (2014), D is based on Lu and Liu (2013), s is based on Yue and Liu (2006), c is based on Khouja et al. (2013), l is based on Liu et al. (2014), U is based on Huang and Yang (2015), and p_r, p_m are based on Bose and An and (2007). However, ρ_r and ρ_m are hypothetical because of the lack of data. Referring to the parameters in the above literature, we set up the basic parameters as follows: $s=40$, $c=60$, $l=10$, $D=510$, $U=210$, $p_r=320$, $p_m=300$, $\rho_r=0.2$, $\rho_m=0.3$, $\alpha=0.6$; and the constraint conditions of the game model can be satisfied. That is, the chosen parameters must satisfy the constraints we mentioned in order to make the models feasible and meaningful. In the following numerical experiments, some parameters may be varied from the standard setting to perform sensitivity analysis. In Figure 2, let $f=270$, $\theta=0.7$ and $f=300$, $\theta=0.7$ respectively, we can see that the retailer's expected utility is monotonically increasing as her risk-averse indicator η increases, this verifies Proposition 4.2 (1).

Figure 2 The impacts of η on the retailer's expected utility



Next, we conduct three cases of simulations to verify Proposition 4.2 (2). We assume $s=40$, $c=60$, $l=10$, $\eta=0.8$, $U=210$, $p_r=320$, $p_m=300$, $\rho_r=0.2$, $\rho_m=0.3$, $\theta=0.7$, $\alpha=0.6$. Let $D=510$ as the first case, $D=570$ and $D=620$ as the second and third cases. The threshold values f_r are equal to -72.1538, 137.8462 and 312.8462 respectively. From Figure 3, we can see that the retailer's expected utility is monotonically decreasing, concave or monotonically increasing in f.

Figure 3 The impacts of f on the retailer's expected utility



In the following proposition, we will examine the impacts of f on the manufacturer's expected profit from another perspective. We use the relative expected profit to measure the manufacturer's performance. Assume consumer's post-purchase valuation V follows a uniform distribution on $[0,\overline{v}]$ where $\overline{v} > p_m$ and this assumption is commonly used in consumers return literature such as Li and Xu et al. (2014) and Liu et al. (2014). Thus the manufacturer's relative profit is defined as the difference between returns policy (RP) and no returns policy (NRP) (i.e. $\Delta\pi_m = E(\pi_m)|_{RP} - E(\pi_m)|_{NRP}$). If $\Delta\pi_m > 0$, then providing the returns option to consumers is better off for the manufacturer. If $\Delta\pi_m \le 0$, then the manufacturer will not offer returns service. The next proposition characterizes the manufacturer's best responses given η .

Proposition 4.3: Given the retailer's risk-averse indicator η, there exists the thresholds v_1 and v_2 such that:

(1) if $\overline{v} \le v_1$, then it is optimal for the manufacturer to offer a **partial** returns policy;

(2) if $v_1 < \overline{v} \le v_2$ and $0 < \underline{\eta} < \eta < \overline{\eta} \le 1$, then it is optimal for the manufacturer to offer a **partial** returns policy;

(3) if $v_1 < \overline{v} \le v_2$ and $0 < \overline{\eta} < \eta \le 1$, then it is optimal for the manufacturer to offer a **full** returns policy;

(4) if $\overline{v} > v_2$, then it is optimal for the manufacturer to offer the **full** returns policy,

$$\text{where} \quad v_1 = \frac{Y}{X - \dfrac{\rho_r (p_r - s)[(D-U)\theta + \alpha p_m - p_r - \rho_r p_m]}{4U\theta}},$$

$$v_2 = \frac{Y}{X - \dfrac{\rho_r (2p_m - p_r - c)}{2} + \dfrac{\rho_r^{\,2} p_m (2p_m - p_r - c)}{2[(D-U)\theta + \alpha p_m - p_r]}},$$

$$\overline{\eta} = \frac{\rho_r (p_r - s)[(D-U)\theta - \rho_r p_m + \alpha p_m - p_r]}{-4U\theta M}, \; M = \frac{Y}{\overline{v}} - X \;,$$

$$X = \rho_m (p_m - c) - \frac{\rho_r (p_r - c)}{2},$$

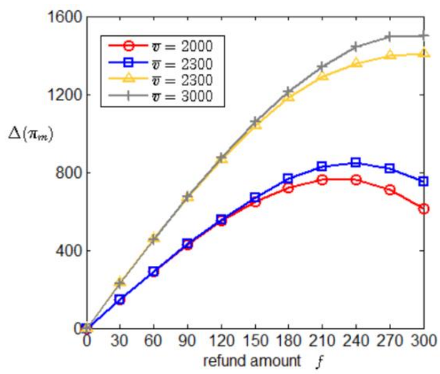
$$Y = 3\rho_m p_m{}^2 - 2\rho_m (s-l) p_m + (2p_m - s + l)[(1-\theta)D + \alpha p_r - p_m].$$

Proposition 4.3 states that the manufacturer's optimal returns policy can be characterized by the highest consumer's valuation of the product. Prior to purchase, consumers are uncertain about the product's fit with their tastes. A consumer faces a distribution of potential values which she might obtain after product trial. Consumers know the distribution of V , but no individual knows the exact value until she buys the product and tries it. Note that if $v > p_m$ means a consumer is satisfied with the product. Therefore, a higher $\overline{v}$ means the proportion of the satisfied consumers is larger, or equivalently the proportion of the returns is smaller. A simple but useful construct to capture the effect of $\overline{v}$ on the selection on returns policy is to assume that the market consists of three types of consumers. One group has high valuation of the product, another group has low valuation and the rest consumers have moderate valuation of the product. Specifically, the high-valuation type is marked as $V_H = V$, the low-valuation type is $V_L = \psi_L V$ and the moderate valuation type is $V_M = \psi_M V$ ($0 < \psi_L < \psi_M < 1$) (Li and Xu et al., 2014). Thus the distributions of the high-valuation type and the low-valuation type are $V_H \sim U[0, \overline{v}]$, $V_L \sim U[0, \psi_L \overline{v}]$ and $V_M \sim U[0, \psi_M \overline{v}]$ respectively. Obviously, the high-valuation type has higher upper bound of V than the other types.

When the upper bound of V is relatively low (e.g. $\overline{v} \le v_1$), it can be interpreted as that the consumers belong to the low-valuation type. Due to the consumers' low valuation of the product, the manufacturer may experience a relatively high proportion of returns, and therefore tends to offer partial returns policy to mitigate the risk instead of offering the full returns policy. Further, when the upper bound of V is moderate, the manufacturer's optimal returns policy also counts on the retailer's risk-averse level. When the retailer's risk-averse level is relatively high (i.e. η is smaller than $\overline{\eta}$), for the manufacturer, even if consumers has higher valuation compared with the low-valuation type, he will also provide the partial return policy to alleviate channel competition. However, if the retailer's risk-averse level is low (i.e. η is greater than $\overline{\eta}$), the manufacturer could provide the full returns policy to pursue higher profit. Moreover, when the upper bound of V is relatively high (e.g. $\overline{v} > v_2$), our results show that a full returns policy is optimal for the manufacturer. Under this situation, consumers belong to the high-valuation type. In practice, consumers with higher valuation are willing to pay more and they also value service more than the low-valuation type. Besides, the proportion of the returns of high-valuation type is smaller than the low-valuation type. Therefore, the manufacturer is motivated to offer a generous full returns policy to attract more high type consumers.

The proof is found in Appendix 4. We use four experiments to verify the Proposition 4.3. The data in Figure 4 is set as $s = 40$, $c = 60$, $l = 10$, $D = 510$, $U = 210$, $p_r = 320$, $p_m = 300$, $\rho_r = 0.2$, $\rho_m = 0.3$, $\theta = 0.7$, $\alpha = 0.6$. Here by calculation, we obtain $v_1 = 2247.6$, $v_2 = 2362.5$ and $\overline{\eta} = 0.8203$. When $\overline{v} = 2000 < v_1$, $\eta = 0.8$ the manufacturer should adopt partial returns policy, which is consistent with Proposition 4.3 (1). When $v_1 < \overline{v} = 2300 < v_2$ and $\eta = 0.8 < \overline{\eta}$, the manufacturer should adopt partial returns policy, which verifies Proposition 4.3 (2). When $v_1 < \bar{v} = 2300 < v_2$ and $\eta = 0.9 > \bar{\eta}$, the manufacturer should adopt full returns policy, which verifies Proposition 4.3 (3). When $\bar{v} = 3000 > v_2$ and $\eta = 0.8 > \bar{\eta}$, the manufacturer should adopt full returns policy, which is consistent with Proposition 4.3 (4).

Figure 4 The impacts of f on the manufacturer's relative profit



Next we will extend the model to the case with an endogenous refund amount. When the refund amount f is an endogenous decision variable, the manufacturer will first decide his optimal returns policy and the wholesale price, then the retailer will choose her optimal order quantity based on the manufacturer's decisions. Using standard backward induction, we obtain the equilibrium solution ($\hat{w}^*$, f^*, $\hat{q}^*$) as follows:

Corollary 4.1: When the refund amount is an endogenous decision variable, there exist the threshold values v_1 and v_2 such that the unique equilibrium solutions ($\hat{w}^*$, f^*, $\hat{q}^*$) are derived as follows:

(1) if $\bar{v} \le v_1$, then $f^* = \hat{f}$,

(2) if $v_1 < \bar{v} \le v_2$ and $0 < \underline{\eta} < \eta < \bar{\eta} \le 1$, then $f^* = \hat{f}$,

(3) if $v_1 < \bar{v} \le v_2$ and $0 < \bar{\eta} < \eta \le 1$, then $f^* = p_m$,

(4) if $\bar{v} > v_2$, then $f^* = p_m$,

$$\text{and } \hat{w}^* = \frac{p_r - s}{4U\eta\theta}[(D-U)\theta - \rho_r f^* + \alpha p_m - p_r] + \frac{p_r + c}{2},$$

$$\hat{q}^*(\hat{w}^*, f^*) = (D-U)\theta - \rho_r \hat{f}^* + \alpha p_m - p_r + \frac{2U\eta\theta(p_r - \hat{w}^*)}{p_r - s},$$

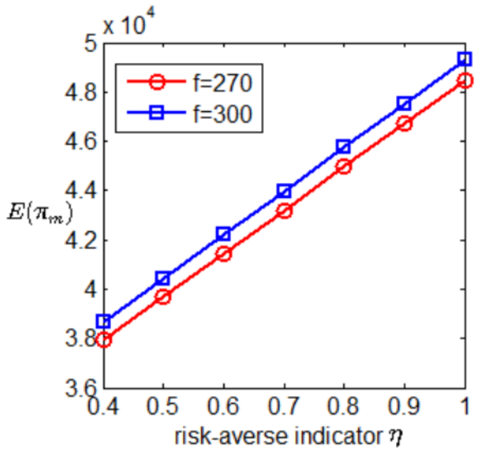
where $v_1, v_2, \bar{\eta}$ are defined in Proposition 4.3, $\hat{f} = \dfrac{-\hat{B} + \sqrt{\hat{B}^2 - 4\hat{A}\hat{C}}}{2\hat{A}}$, $\hat{A} = -3A$, $\hat{B} = -2B$, $\hat{C} = -C$, A, B and C are shown in Appendix 4.

The proof is given in Appendix 5. From Corollary 4.1, we can see that when f is endogenous, the optimal decisions of the manufacturer and the retailer are not exclusive but are divided into two cases according to different scenarios. This is because f is restricted between 0 and p_m. Furthermore, the criteria of the optimal f are the same with those in the Proposition 4.3. As reflected in Corollary 4.1, when the the highest consumer's valuation of the product $\overline{v}$ is low, the optimal solution of f is equal to $\hat{f}$ and the manufacturer should provide the partial return policy. When $\overline{v}$ is high enough to surpass a certain threshold v_2, the manufacturer may provide the full return policy to stimulate larger demand. When $\overline{v}$ is moderate, the optimal solution of f is also related to the retailer's risk-averse level. When the retailer's risk-averse level is relatively high, for the manufacturer, he should provide the partial return policy to alleviate channel competition. However, if the retailer's risk-averse level is low, the manufacturer could provide the full returns policy to pursue higher profit.

Proposition 4.4: Given the refund amount f, when η increases in the interval $[\underline{\eta}, 1]$, the manufacturer's expected profit is increasing.

The proof is given in Appendix 6. Proposition 4.4 implies that the manufacturer's expected profit is always increasing in η. This property is shown in Figure 5 using the same data with Figure 2. For the cases of $f = 270$, $\overline{v} = 5000$ and $f = 300$, $\overline{v} = 5000$, it can be seen from Figure 5 that the manufacturer's expected profit is increasing as η increases in $[0.4,1]$.

Figure 5 The impacts of η on the manufacturer's expected profit



Through the analysis of the manufacturer's expected profit function, one can see that the change of η only affects manufacturer's profit on his traditional channel. This effect is exerted by the influence of η on the wholesale price and the order quantity. When η increases, the order quantity will increase with it. However, the wholesale price of the manufacturer will decrease at the same time. Even though the wholesale price and the order quantity have two different trends, we find that manufacturer's expected profit is monotonically increasing in η . From the proof of Proposition 4.1, each unit increase in η is associated with unit increase in order quantity. However, as becomes larger, each unit increase in is associated with less decrease in the wholesale price. Putting together, the manufacturer's expected profit is always increasing as increases.

5 Supply chain coordination

Channel coordination is an important issue in dual-channel supply chains. In this section, we aim to design a contract to coordinate the decentralized dual-channel supply chain when the refund amount is endogenous. Before discussing the contract mechanism, we first analyse the centralized dual-channel supply chain as a benchmark model. Gan et al. (2004, 2005) gave a definition of coordination for supply chains involving risk-averse agents under VaR. We refer to their definition of coordination and give a new definition under the CVaR criterion. Supply chain coordination is described as follows: *A supply chain is coordinated if the following two conditions are satisfied: 1) Each agent's profit cannot be less than that in the decentralized situation; 2) The expected profit of the whole supply chain is equal to that in the centralized situation*. Under the centralized situation, the decisions for the supply chain are the retailer's order quantity and refund amount in the online channel, thus the profit of the centralized supply chain is as follows:

$$\pi_{SC}^{C}=\pi_r+\pi_m=(p_r-c)\cdot q-(p_r-s)[q-D_r]^{+}+(p_m-c)\cdot\bar{G}(f)D_m+(p_m-c-f+s-l)\cdot G(f)D_m \quad (10)$$

And then the centralized supply chain's problem is listed below:

$$\max_{q,f} E[\pi_{SC}^{C}] \quad (11)$$

$$\max_{q,f} E[\pi_{SC}^{C}] \quad (12)$$

According to the KKT (Karush-Kuhn-Tucker) condition, the first-best solutions exist. The proof of the concavity of $E[\pi_{SC}^{C}]$ with respect to (q,f) and the first-best solutions $\{q_c^*, f_c^*\}$ are given in the Appendix 7.

From our definition, we can see that if a contract can coordinate the dual-channel supply chain with risk-averse agents, firstly it should make sure that the risk-averse retailer places an order q_c^* under such contract. At the same time, the manufacturer has the incentive to choose the first-best refund amount f_c^* . In addition, both agents' performance should be Pareto improvements. As mentioned earlier, a risk-averse retailer undertakes double pressure from online channel's returns service and uncertainty demand in the retail channel. As a result, the manufacturer should provide the required downside protection to the retailer so that the retailer has the incentive to increase her order quantity. Based on the retailer's utility function, we find that the retailer's risk-averse behaviour is mainly reflected in the expected surplus stock and the deprived demand from the online channel. Therefore, on one hand, the manufacturer could buy back retailer's unsold products. On the other hand, the manufacturer could share a proportion of online channel's revenue with the retailer.

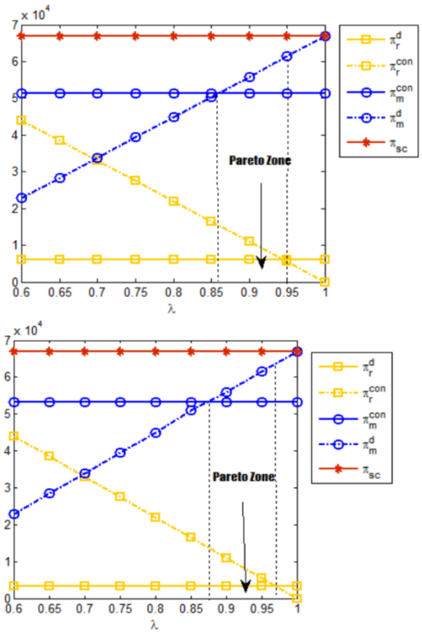
Thus, we design a buyback revenue-sharing contract to coordinate the decentralized dual-channel supply chain. The manufacturer buys back retailer's unsold inventory at a buyback price $b\ (<w)$ per unit and shares a portion λ of the online channel's revenue with the retailer. The following Proposition describes the coordination of the decentralized dual-channel supply chain.

Proposition 4.5: If the contract parameters (w_b^* , b , λ) satisfy the following conditions:

$$w_b^* = p_r - \frac{(p_r - b)(p_r - c)}{\eta(p_r - s)} \text{ and } \lambda = 1 - \frac{\rho_r(p_r - b)(p_r - c)}{\eta\rho_2(p_r - s)p_r},$$

then the buyback-revenue sharing contract can coordinate the dual-channel supply chain with the risk-averse retailer.

Figure 6 Coordination of the dual-channel supply chain with the risk-averse retailer, (a) full returns policy, (b) partial returns policy



(a) (b)

The proof is given in Appendix 8. Next, we resolve the problem of Pareto improvements by using the numerical experiments. We assume $s = 40$, $c = 60$, $l = 10$, $D = 510$,
$U = 210$, $p_r = 320$, $p_m = 300$, $\rho_r = 0.2$, $\rho_m = 0.3$, $\alpha = 0.6$, $\theta = 0.7$, $\eta = 0.8$ and $\bar{v} = 5000$. In Figure 6, we can see that there is a Pareto zone with the share proportion λ in each situation where the optimal refund amount is full (i.e. Figure 6(a)) and partial (i.e. Figure 6(b)).In the Pareto zone, the retailer's expected utility and the manufacturer's expected profit are both higher under the contract than those in the decentralized supply chain. The sum of the retailer's and the manufacturer's expected profit under the contract is the same with the total expected profit in the centralized situation.

6 Discussion

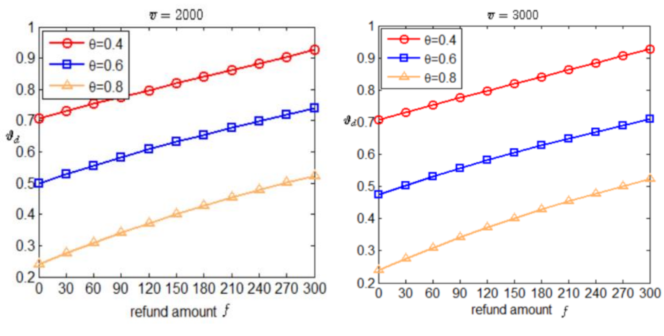
We now explore two additional impacts of the consumer returns policy in the dual-channel supply chain. Due to the difficulty of analytical analysis, we resort to numerical analysis. As our introduction mentioned, the manufacturer is the leader in the supply chain. Through opening an online channel, the manufacturer is competing with the retailer by carving up basic demand in the market. Besides, offering the consumer returns in the online channel may enhance the manufacturer's competition and leads to more severe channel conflict. As a result, manufacturer encroachment and consumer returns policy will bring the retailer double pressure on surviving in the market. Therefore, by focusing on the consumer returns policy, we aim to develop insights regarding the following questions: How to measure the competitiveness of the manufacturer in his online channel? By offering the consumer returns in the online channel, what effect might have on the competitiveness of the online channel? In addition, it is interesting to investigate the impact of the refund amount on the retailer's viability in the supply chain. Based on the numerical results, we firstly make the following observations.

Observation 1: When the manufacturer offers the consumer returns policy, the competitiveness of the online channel in the supply chain is monotonically increasing as the refund amount increases. When the degree of consumer loyalty to the retail channel is larger, the competitiveness of the online channel is lower.

Observation 2: When the manufacturer offers the consumer returns policy, the retailer's profit share in the supply chain is increasing or firstly increasing then reducing as the refund amount increases. When the degree of consumer loyalty to the retail channel is larger, this viability becomes greater.

First, we define a ratio $\vartheta_d = E(\pi_d)/\pi_{SC}$ to evaluate the competitiveness of the online channel in the supply chain. $E(\pi_d)$ is the expected profit of the online channel and π_{SC} is the total expected profit of the supply chain. The profit of the entire supply chain π_{SC} is regarded as a profit "pie". We interpret ϑ_d as the competitiveness of the online channel from the angle of profit share. If ϑ_d is larger, the competitiveness of the online channel in the supply chain becomes greater. We illustrate the impact of consumer returns policy on ϑ_d in Figure 7. The basic data are the same as that in Figure 2. Furthermore, we set $\bar{v} = 2000$ and $\bar{v} = 3000$ respectively in this example to investigate the impact of consumer valuation uncertainty.

Figure 7 The impact of f on competitiveness of online channel, (a) $\bar{v} = 2000$, (b) $\bar{v} = 3000$



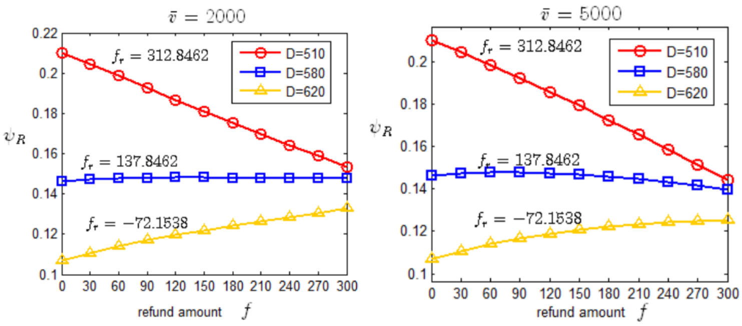
(a) (b)

From Figure 7 we can see that ϑ_d monotonically increases in f . This means larger refund amount leads to greater competitiveness of the online channel. The reason behind the above result is intuitive. Consumers are unable to actually see and inspect the products before purchasing. Offering the consumer returns policy can enhance consumers' purchasing confidence and the competitiveness of the online channel under the dual-channel supply chain. For the consumer, the more generous the returns policy is, the more purchase intention they have. In fact, Rogers and Tibben-Lemke (1999) conducted a survey and found that among the respondents, 63% believe that one of the most important tools for Internet manufacturers/retailers to stay competitive is to offer clear and attractive return policies. Therefore, higher refund amount leads to greater competitiveness.

When θ is lower, the share of basic demand going to the direct channel (e.g.$1-\theta$) is relatively larger. Therefore, the competitiveness of the online channel is decreasing as θ increases. Besides, according to Proposition 4.3, the manufacturer's optimal returns policies are partial returns and full returns under the data set in Figure 7(a) and 7(b) respectively. By comparing these two figures, we find that the competitiveness of the online channel is always increasing in the refund amount.

Figure 8 verifies Observation 2. $\psi_r = CVaR(\pi_r)/\pi_{SC}$ denotes the retailer's profit share in the supply chain. This indicator is on behalf of a firm's profitability. Chow et al. (2015) used minimum profit share ratio (MPSR) to define as the retailer's profit over the whole supply chain profit. They mentioned that MPSR related to the retailer's fairness concern. The larger ψ_r means the retailer's survival ability is greater. Through Figure 8, we can see that when the market demand is low (e.g. $D = 510$), the retailer's profit share is decreasing in the refund amount f . When the market demand is moderate (e.g. $D = 580$), the retailer's expected utility is concave in f . Recall that in the Proposition 4.2, we give a threshold f_r to judge the trend of the retailer's expected utility in f and the thresholds are also showed in Figure 8. When $D = 620$, $f_r = 312.8462$, thus the retailer's expected utility is monotonically increasing in f . Consequently, the growing speed of ψ_r is larger when f increases. Surprisingly, when the retailer's basic market demand is relatively high (e.g. $D = 620$), we find that providing the consumer returns policy in the online channel may benefit the retailer from both perspectives of her expected utility and market profit share.

Figure 8 The impacts of f on retailer's profit sharing in the supply chain, (a) $\bar{v} = 2000$, (b) $\bar{v} = 3000$



(a) (b)

7 Extensions

We now consider several variations of the basic model to show that our main insights are robust.

7.1 Remanufacturing the returned products

In this section, we assume all the products returned in the online channel are remanufactured by the manufacturer. The unit cost of manufacturing a new product is c_n and c_r is the unit cost of remanufacturing a returned product into a new one with $c_r < c_n$.

$\tau = G(f)D_m/(D_r + D_m)$ is the remanufactured rate and denotes the fraction of remanufactured products from all products in the market. Similar to Savaskan et al. (2004), decisions in the supply chain can be considered in a single-period setting and the average unit cost of manufacturing can be written as $\bar{c} = c_n(1-\tau) + c_r\tau$.

Figure 9 The impacts of η on members' performance

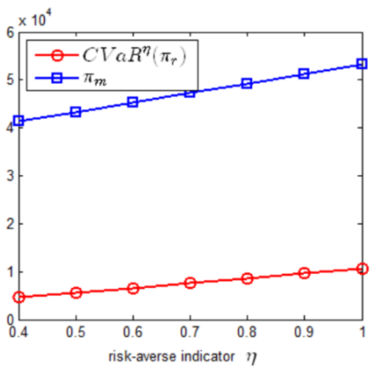
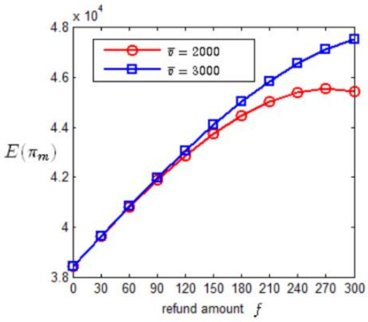
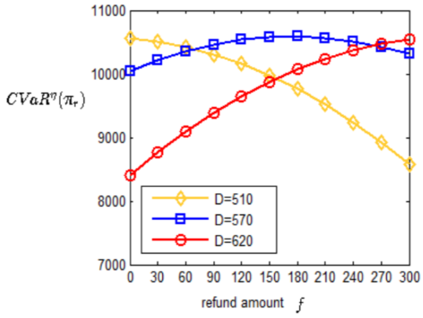


Figure 10 The impacts of f on members' performance, (a)manufactures' expected profit, (b)retailer's expected utility



(a)



(b)

The profit of the manufacturer and the utility of the retailer and are the equilibrium solutions are given in Appendix 9. Due to the complexity of equilibrium solutions, we use numerical analysis to investigate the impacts of the retailer's risk-averse level and the refund amount. The data are set as follows: $s=40$, $c_n=45$, $c_n=42$, $l=10$, $D=510$, $U=210$,

$\theta=0.7$, $\alpha=0.6$, $p_r=320$, $p_m=300$, $\rho_r=0.2$, $\rho_m=0.3$, $\overline{v}=5000$. For the given $f=300$, Figure 9 shows that when the retailer is more risk averse, both agents' performance are lower. Given $\eta=0.8$, in Figure 10 (a), we can see that the manufacturer should provide full returns policy when the consumer has higher valuation while a partial returns policy is more profitable to the manufacturer if the consumer has low valuation. Figure 10 (b) indicates that the retailer's expected utility may increase, decrease or first increase then decrease with f increasing. In conclusion, the introduction of remanufacturing process does not affect our main results.

7.2 Endogenous pricing strategy

In this section, we consider the case when prices are endogenous. In this case, the manufacturer decides the wholesale price w and the online selling prices p_m at first and then the retailer determines her order quantity q_r and the retail price p_r. The objective functions are the same with equations (6) and (7). For any given w and p_m, the retailer's reaction functions satisfy following equations:

$$q_r = 2U\eta\theta\frac{p_r - w}{p_r - s} - \rho_r f + \alpha p_m - p_r + \theta D - U\theta \tag{13}$$

$$(-\rho_r f + \alpha p_m - 2p_r + \theta D - U\theta + w)(p_r - s)^2 + 2U\eta\theta(p_r - w)(p_r - s) - U\eta\theta(p_r - w)^2 = 0 \tag{14}$$

Taking into account the retailer's reaction functions, the manufacturer decides w and p_m. Due to the complexity of calculation, we cannot obtain the analytical expressions of

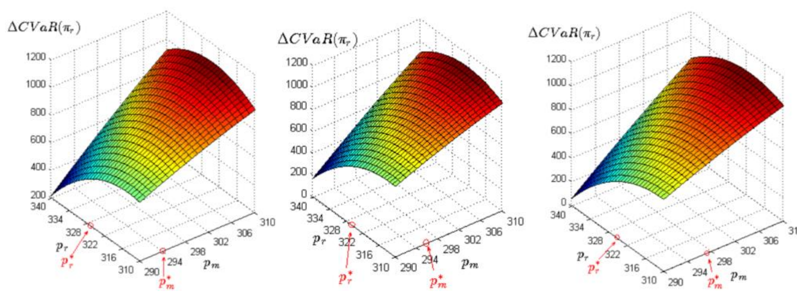
w and p_m. Inspired by Zhang et al. (2015), we design an approximating algorithm to derive the approximate optimal solutions in this problem. The algorithm is given in the Appendix 10.

When the prices are endogenous, we obtain the similar results with Proposition 4.1 about the impacts of f and η on w and q_r and the results by the numerical experiment are shown in the Appendix 11. At the same time, we find that the impacts of η on the members' performance continue to hold as the previous results. We then conduct a few comparative numerical studies to explore the characteristics of the models under two different pricing scenarios and identify the differences with respect to the members' performance.

In the experiments, let $s = 40$, $c = 60$, $l = 10$, $D = 510$, $U = 210$, $\theta = 0.7$, $\alpha = 0.6$, $\rho_r = 0.2$, $\rho_m = 0.3$, $\bar{v} = 5000$. The results are shown in Figure 11 to Figure 14, where X-axis and Y-axis represent exogenous p_m and p_r respectively and the value of the prices is set to the certain intervals which contain the approximate optimal solutions p_m^* and p_r^*. The approximate optimal solutions of endogenous p_m and p_r are also shown in every figure. Then the member's performance under the endogenous pricing is used as a benchmark to obtain the performance differences between two scenarios in the Z-axis.

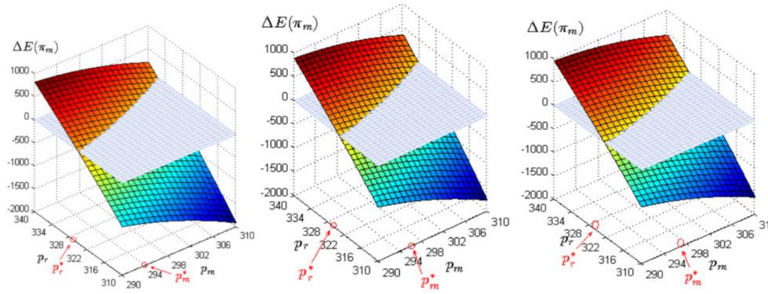
First given $\eta = 0.8$, we investigate the differences of the members' performance under exogenous and endogenous pricing with changes in f. From Figure 11 and 12, we can see that endogenize pricing does not always add value to the retailer and the manufacturer. This is because the freedom of price decision-making in a Stackelberg game will lead to more serious channel confliction and double-marginalization. Besides, with f increasing, the expected utility difference of the retailer is decreasing and the expected profit difference of the manufacturer is increasing. This result is intuitive because with higher refund amount, the online channel is more appealing than the traditional channel and will attract more consumers.

Figure 11 The differences in retailer's expected utility under exogenous and endogenous price with changes in f, (a) $f = 190$, (b) $f = 200$, (c) $f = 210$



(a) (b) (c)

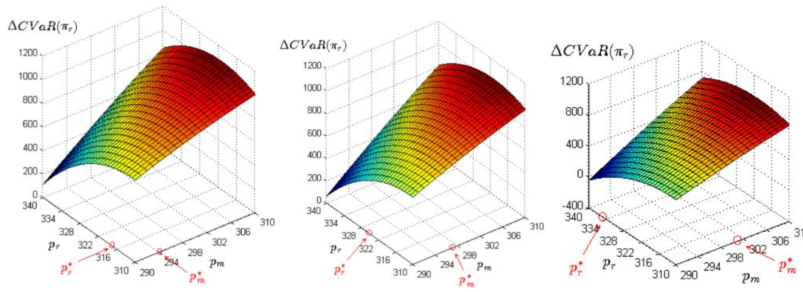
Figure 12 The differences in manufacturer' expected profit under exogenous and endogenous price with changes in f, (a) $f = 190$, (b) $f = 200$, (c) $f = 210$



(a) (b) (c)

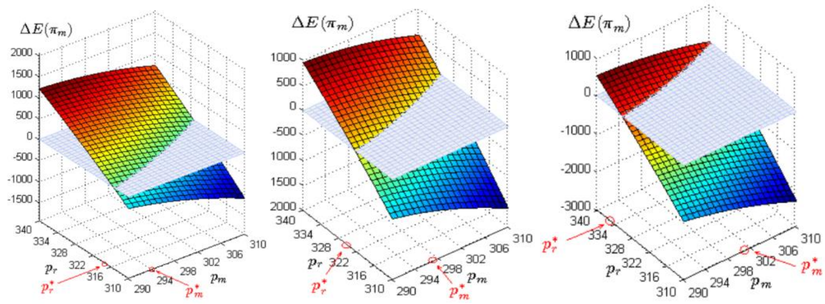
Second given $f = 210$, we investigate the differences in the members' performance under exogenous and endogenous prices with changes in η. Recall that in both exogenous and endogenous pricing scenarios, both members' performance increase with η increasing. However, we can see that when the retailer's risk-averse level is higher, both $\Delta CVaR(\pi_r)$ and $\Delta E(\pi_m)$ decreases in Figure 13 and 14. This result also indicates when the manufacturer and the retailer set their optimal prices, both members response more rapidly to the change of η. Although the retailer's expected utility and the manufacturer's expected profit increase with η increasing in the exogenous pricing scenario, compared with it, both members' performance raise more quickly in the endogenous pricing scenario. Therefore the differences of the performance $\Delta CVaR(\pi_r)$ and $\Delta E(\pi_m)$ will go down instead.

Figure 13 The differences in retailer's expected utility under exogenous and endogenous price with changes in η, (a) $\eta = 0.7$, (b) $\eta = 0.8$, (c) $\eta = 0.9$



(a) (b) (c)

Figure 14 The differences in manufacturer' expected profit under the exogenous and endogenous price with changes in η, (a) $\eta = 0.7$, (b) $\eta = 0.8$, (c) $\eta = 0.9$



(a) (b) (c)

8 Conclusion

In this paper, we develop a dual-channel supply chain consisting of a risk-neutral manufacturer and a risk-averse retailer. The manufacturer offers a consumer returns policy in the online channel, in which consumers face valuation uncertainty. We use conditional value-at-risk (CVaR) criterion to evaluate the risk-averse behaviour of the retailer. We examine how customer returns policy and risk-averse behaviour influence the equilibrium solutions and supply chain agents' performance.

It is found that the degree of the retailer's risk aversion will affect the agents' optimal decisions and their performance. A higher risk-averse indicator (i.e. less risk-averse behaviour) leads to larger order quantity and lower wholesale price. If the retailer is more risk-averse, both agents' performance will decrease monotonically. One of our main conclusions is that the manufacturer's optimal returns policy is related to the consumer types. Facing with the low-valuation type, the manufacturer should offer a partial returns policy. Under this situation, a full returns policy is so generous that the manufacturer has to bear too much costs of returns. On the contrary, the manufacturer is motivated to offer a generous full returns policy to attract high type consumers. If the consumer has moderate valuation of the product, the optimal returns policy depends on the retailer's risk-averse level. What surprises us is that the retailer's expected utility may monotonically increase in the refund amount under the double pressure of manufacturer encroachment and returns service. We obtained a set of threshold values to characterize the relationship between the retailer's expected utility and the manufacturer's refund amount, which can be used to determine when the retailer would achieve the maximum expected utility under a given risk-averse level. In addition, a buyback revenue-sharing contract is developed to coordinate the decentralized dual-channel supply chain in relation to the centralized benchmark model. Numerical examples verified our analytical results. In addition, we use two numerical studies to investigate the impacts of the refund amount on the competitiveness of the online channel and on the retailer's viability in the supply chain.

Further research may be done in the following directions. First, we only consider the situation in which the retailer has risk-averse behaviour, it may also be interesting to investigate the situations that both agents have risk-averse behaviour in a dual-channel supply chain. Second, the information asymmetry in the supply chain and its impact on the agents' decisions may worth further investigation.

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