Journal of Retailing and Consumer Services 47 (2019) 104–115

Contents lists available at ScienceDirect

Journal of Retailing and Consumer Services

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

Impacts of returns policy under supplier encroachment with risk-averse retailer

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ARTICLE INFO

Keywords:
Consumer returns policy
Risk aversion
Supplier encroachment

ABSTRACT

This paper investigates the effects of consumer returns policy and retailer's risk aversion on the behavior of supply chain members under supplier encroachment. We build a theoretical model of a dual-channel supply chain consisting of a risk-neutral supplier and a risk-averse retailer. Both channels provide consumer returns service. We thus examine the optimal pricing decisions for the supplier and the retailer and analyze the impacts of consumers' sensitivity to returns policy on firms' pricing strategies, product demands and the performance under retailer's different risk attitudes. We also consider the role of competition when consumers facing multiple suppliers or multiple retailers. It is shown that when consumers are too sensitive to the returns policy, providing consumer returns policy may hurt the online demand and the total demand. An increased risk aversion level of retailer may lead to a smaller expect utility for the retailer while a larger profit for the supplier. Surprisingly, the number of retailers does not affect the optimal decisions, only affects the competitive retailers' expected utility. Furthermore, we find that a two-part tariff contract could coordinate the supply chain under the supplier encroachment when both members are risk-neutral.

1. Introduction

When the upstream supplier in a supply chain sells products directly to consumers in the Internet, encroachment occurs in the downstream market which is called as supplier encroachment (Arya et al., 2007; Li et al., 2014; Ha et al., 2016). For example, cosmetics suppliers such as Estée Lauder and Johnson & Johnson sell their products through the traditional retail channel as well as their own websites; fashion industry makers such as Nike, Adidas and Levi Strauss and Co. (Levi's) also sell products through independent retailers as well as their own Internet channels. Samsung and Sony in electronics industry, they all have their own direct channels and traditional reselling channels. In response to intensive competition in the online and offline environments (dual-channel supply chain) (Yan and Bhatnagar, 2008), the importance of services in a competitive dual-channel market is well emphasized (Yan and Pei, 2009), where consumer returns policy as a service guarantee tool has been widely implemented by firms (Heiman et al., 2001). Consumer returns policy helps retailers attract consumers and keep consumers loyalty. Especially, for the suppliers, providing consumer returns policy can alleviate the concerns for the misfits of online products. For example, retailers such as Wal-Mart and Sephora provide 100% money-back guarantees for consumer returns in their traditional channels. As their suppliers, Samsung and Estée Lauder also promise full returns policies in their online sales for Internet transactions (http://www.samsung.com; http://www.EsteeLauder.com).

It has been demonstrated that more than 70% of consumers will consider returns policies before their purchasing (Trager, 2000). According to Thaler (1983), the consumers' purchase intentions depend not just on the selling prices they pay, but also on the consumers' perceived value of what they can receive in the deal, such as consumer services. Since consumers are unable to assess products' real value under most cases, consumer returns policy is of great significance for consumers. Especially for the online channel, returns policy can alleviate consumers' worry of valuation uncertainty. Further, the more generous returns policy is (i.e., the refund amount is larger), the lower the consumers' perceived risk of a purchase is. Therefore, consumers' utilities depend not only on the selling price of the product, but also on the positive effect of returns policy. However, consumers' heterogeneity leads to the perception discrepancy of returns policy. The same returns policy will bring different utility to heterogeneous consumers. This paper will study consumer returns policy in a dual-channel supply chain. We design returns policy provided by dual channels. Further, we discuss how the perception discrepancy of consumers on returns policy will affect the market demand, both members' optimal decisions and

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https://doi.org/10.1016/j.jretconser.2018.11.011
Received 10 October 2017; Received in revised form 9 November 2018; Accepted 16 November 2018
0969-6989/

their performances in supply chains.

Obviously, supplier encroachment by online channels has significant impacts on the retailers in the retail channels, that is, the cannibalization effect to the retail channel is becoming more and more serious (Arya et al., 2007; Li et al., 2014, 2015), because the suppliers' online channels are carving up the retailers' original demands which bring retailers great challenge in demand information forecasting and customer relationship management. Meanwhile, offering returns policy can remedy the Achilles heel of online channels (e.g., lack of experience and delays of shipping) and then enhances the confidence of consumers' online shopping. All of these may lead to a higher degree of the demand uncertainty and greater competitive pressure for retailers. Therefore, the retailers may behave in a risk-averse way (Choi et al., 2008). In fact, many researchers have combined the risk-averse behavior into the supply chain and analyzed its impacts on the decisions (e.g., Liu et al., 2012; Xu et al., 2014). In this paper, we also consider the retailer's risk aversion into the decision framework in the supplier encroachment situation.

This paper discusses a supply chain where the supplier encroaches the retailer's distribution channel by the Internet. That is, the supplier sells his products through his own online channel and the retailer's retail channel and both online and offline channels provide product returns service. Consumers are heterogeneous in product valuation and their utility depends not only on the selling price of the product, but also on the refund amount in returns policy. Facing the encroachment of the supplier, the retailer may have risk-averse behavior. Based on the above problem, we design two scenarios without or with the retailer's risk behaviors to reveal the following issues: How to set the optimal prices in both the online channel and the offline channel? What are the impacts of the consumers' sensitivity to returns policy and the retailer's risk-averse indicator on the optimal pricing strategies, product demands and firms' performance? Whether the optimal decisions and firms' performance changes when multiple suppliers or multiple retailers exist in the market? What contract can be used to coordinate the supply chain in the presence of consumer returns and the risk-averse retailer? To answer these questions, we establish two scenarios based on retailer's different risk attitudes and derive optimal decisions. Through using Mean-Variance (MV) approach (Markowitz, 1959), we can evaluate the impacts of risk level. Also we examine the impacts of returns policy on the pricing strategies and the channel demands. We further compare the two scenarios with respect to members' optimal decisions, channel demands and supply chain performance.

The rest of this article is organized as follows. The relevant literature is reviewed in Section 2. Section 3 describes the problem background and two scenarios' framework. In Section 4, we analyze the impacts of consumer returns policy on agents' decisions and performance and compare two scenarios. Section 5 describes several model extensions. Section 6 is the conclusions of this paper. Managerial implications and limitations are summarized in Section 7.

2. Literature review

Supplier encroachment has been extensively studied in supply chain literature. The evolution of this field can be mainly divided into five aspects. The first and early aspect focuses on the impacts on members' performances when the supplier opens an online channel (Chiang et al., 2003; Arya et al., 2007; Yan, 2008; Xiong et al., 2012). These studies explore firms' different channel selection strategies and discuss the impacts of the suppliers' direct channel on supply chains. Later, some literature pays more attention to investigate members' pricing strategies under the different types of game theory (Manufacturer Stackelberg, Retailer Stackelberg and Vertical Nash) in dual channel supply chains (Cai, 2010; Zhang et al., 2012; Lu and Liu, 2013). Third, a few researches introduce retail services (Yan and Pei, 2009; Dan et al., 2012; Pei and Yan, 2015), lead time (Hua et al., 2010; Xu et al., 2012) and advertising issues (Yan and Pei, 2015; Li and Hou et al., 2017) into dual-channel supply chains. They examine how these factors affect the channel demand, profit and pricing strategy. More recently, a few papers focus on multi-channel strategies. Yan et al. (2010) focus on channel integration of multi-channel firms. Ran-Ran et al. (2012), Hsieh et al. (2014) and Dan et al. (2016) explore pricing strategies under the background of multi-channel supply chain. Wallace et al. (2004) study consumer loyalty under multiple channel strategies. They find that multiple channel retailing can be a useful strategy for building customer retailer loyalty. Melis et al. (2015) investigate the drivers of consumers' online channel choice of multi-channel retailers by using the empirical method. The result shows that retailers can reduce consumers' perceived risks of online channel and increase consumer loyalty by increasing assortment. Elms et al. (2016) develop an understanding of the consumers shopping between the internet and store channels by using ethnographic study. Two consumers' internet and store-based shopping practices are presented. They reveal the influence of gender, class, family and kinship on consumers' channel choice. Last but not the least, coordination problem under supplier encroachment is also an important issue in the supply chain management, such as Cai (2010), Yan (2011), Yan et al. (2011) and Li et al. (2016). They all design coordination mechanisms to coordinate the supply chain under the background of the supplier encroachment. However, few researches have considered consumers' returns policy in dual-channel supply chains. Following Chiang et al. (2003), Xu et al. (2012) and Pei and Yan (2015), we use the similar demand functions which involve heterogeneous consumers' valuation and willingness to pay and investigate two members' optimal decisions in the dual-channel supply chain.

Most of references about consumer returns mainly focus on optimal decisions and profits in the single-channel supply chains, such as Chen and Bell (2009), Su (2009) and Hsiao and Chen (2012). Meanwhile, some empirical researches study the impacts of returns policy on consumers purchase intention. For example, Lantz and Hjort (2013) and Pei et al. (2014) point out that full returns policy has a strong positive impact on consumer purchase intention and could increase the market demand. The two recent studies involve the return period into consumer returns policy and both of them assume that consumers' willingness to pay depends on the refund amount and the length of time and they conclude that the longer the return period, the higher the consumer valuation (Ülkü et al., 2013; Xu et al., 2015).

Recently, the studies on the agents' risk aversion have been applied in supply chain management (Liu et al., 2012; Choi et al., 2013) which can be measured using mean-variance (MV) approach (Markowitz, 1959). Under the background of dual-channel supply chain, Xu et al. (2014) study a two-way revenue sharing contract with risk aversion agents under a MV model. B. Li et al. (2017) and Q. Li et al. (2017) consider an asymmetric information issue under a dual-channel supply chain and they also use the MV approach to measure the retailer's risk aversion behavior. However, in terms of the consumer returns issues in supply chain management, there are a limited number of papers considering the agents' risk behavior. Liu et al. (2012) use the MV method to measure a mass customization (MC) manufacturer' risk aversion level when both demand and return are uncertainties. They find that the optimal refund rate, retail price and modularity level decrease in the degree of the manufacturer's risk aversion. Choi et al. (2013) explore full returns policy and no return policy under fashion MC program. By using the MV method, they derive the closed-forms of the optimal solutions under the different returns policy.

Compared with the results of the above literature, the contributions of our paper lie in three aspects. First, we analyze the consumers' returns policy under supplier encroachment. Both the retail and online channels provide returns service for consumers. Most of studies on returns policy focus only on the single channel (Chen and Bell, 2009; Su, 2009; Hsiao and Chen, 2012). Although Pei and Yan (2015) study the retailer's service under dual-channel supply chain, they don't discuss the returns policy in dual-channel supply chains. Second, we incorporate the effect of consumer returns policy into consumer purchase intention. Third, we consider the retailer's risk-averse behavior when the retailer faces both channel competition and demand fluctuation. Different with Liu et al. (2012) and Choi et al. (2013), they consider the seller's risk-averse behavior into consumer returns issues, but only in one echelon supply chain. We use the Stackelberg game to study consumer returns policy in a two echelon supply chain and also with dual distribution channels.

3. Models

3.1. Problem description

In this paper, we consider a single-product dual-channel supply chain with a supplier (he) and a physical retailer (she). The retailer is independent and exclusive, so the retailer only sells the upstream supplier's product in her traditional channel. The supplier can be an independent brand manufacturer, he not only wholesales his products to the retailer, but also sells his products through his online channel to consumers. Therefore, supplier encroachment happens in the terminal market. At the beginning of the sales season, the retailer buys the product from the supplier at the wholesale price w per unit and then decides the retail price p_r per unit in her retail channel. The supplier also sells the product directly from his online channel with an online price p_d per unit. Here assume that the supplier is a Stackelberg leader, that is, the supplier determines w and p_d in the first move in response to the given retailer's retail price. Then the retailer, as a follower, takes the supplier's response function into account for her decision p_r to maximize profit. Finally, when the consumer demand is realized, both the supplier and the retailer gain their revenue. This assumption is widely used in the supply chain channel management literature and is applicable to many settings. In the Stackelberg game, the leader has commitment power, so the first move gives the leader in Stackelberg a crucial advantage.

In addition, both channels provide the full returns policy within a limited time, that is, when consumers are not satisfied with the product they have brought, they can return it to the retailer or the supplier where they bought, and obtain the refund amount $f_i = p_i (i = r, d)$. Note that in reality, there are additional aspects may affect the way consumers assess the returns policy besides the refund amount. Such as the duration, the cost of the return and the terms of the return (Heiman et al., 2001). A few papers such as Hsiao and Chen (2012), Ülkü et al. (2013) and Xu et al. (2015) have discussed these aspects. However, Liu et al. (2014) mentioned that "The amount of the refund can serve as a strategic tool to control and stimulate demand. Specifically, a higher refund amount serves as a signaling mechanism that ensures consumers about the features of the product and eases the decision making." Many literatures use the refund amount as the characteristic of the returns policy, and classify the return policy according to the refund amount, such as Su (2009), Choi et al. (2013), Liu et al. (2014), Yoo (2014), Ruiz-Benitez and Muriel (2014), Jiang et al. (2017). Therefore, we also use the refund amount to evaluate the returns policy in this paper.

Thus, when the selling season begins, a group of heterogeneous consumers decide whether they purchase the product. For analytic simplicity, we assume that consumer population is 1 (Yalabik et al., 2005). Finally, at the end of the sales season, all returned products are salvaged at the prices (Hsiao and Chen, 2014) in both channels.

Facing the competitions between supplier's online channel and the retailer's physical channel, consumers will trade off the utility of two channels when they purchase the product. Consumers utility depends not only on the selling price of the product, but also on consumers' perceived value of what they can receive in the deal (Thaler, 1983). The perceived value in this paper consists of two parts, that is, $V_i + \beta f_i (i = r, d)$. Where the first part V_i denotes the consumer's intrinsic valuation of the product in each channel and it is heterogeneous among consumers (Liu and Xiao, 2008; Ülkü et al., 2013). The second part βf_i denotes the consumer's utility derived from the channel's returns policy, where f_i denotes the refund and $\beta (0 \le \beta < 1)$ denotes the consumer sensitivity to the returns policy.[1] The larger this sensitivity is, the stronger the consumer is willing to pay. Ülkü et al. (2013) and Xu et al. (2015) use similar way to measure the effect of return service on the consumer's valuation.

Then, the consumer's utility is expressed as: $V_i + \beta f_i - p_i$, $i = r, d$. Here we assume $V_r = \mu$ and μ is uniformly distributed over [0, 1]. Here, consumer utility is derived from two parts, one is the valuation of the product and the service in each channel and the other part is the money they have to pay to obtain the product. Even though consumers have to sacrifice time or psychological efforts when go to the store, evidence shows that consumers prefer conventional retail stores more than the web-based direct channels (Chiang et al., 2003; Yan and Pei, 2015). Thus, when consumers buy the product from the online channel, they may have a lower evaluation on the online products because they can't inspect and experience products, helplessness of salespeople, charges for shipping and handling, unable to conduct the physical examination of products and can't obtain them immediately. Thus we introduce a parameter θ to represent the degree of consumer acceptance to the online channel and assume that $V_d = \theta\mu (0 < \theta < 1)$ (Chiang et al., 2003; Li and Huang et al., 2015).

3.2. Full returns policy with a risk-neutral manufacturer and a risk-neutral retailer

Though the descriptions above, we first derive channel demands and give two members' profit functions when both the retailer and the supplier are risk-neutral, we label this scenario as FR-RN (FR is for Full Returns policy and RN is for Risk-Neutral).

To derive channel demands, first we assume that the consumers are perfectly rational,[2] which means that their channel choice mainly depends on their comparison of consumer surplus between two channels. The goal of the rational consumer is to maximize the utility from shopping. They will compare the consumer surplus derived through the online channel with the consumer surplus derived through the traditional channel and choose the channel with higher consumer surplus. Similar assumptions are used in a few papers such as Chiang et al. (2003), Pei and Yan (2015), Ha et al. (2016) and Jiang et al. (2017).

Consumers whose utility derived from the retail channel are positive will buy from the retail channel, that is, $V_r + \beta f_r - p_r \ge 0$, where the marginal consumer whose intrinsic valuation satisfies $\mu^r = p_r - \beta f_r$ belongs to the boundary set. Equivalently, the marginal consumer whose intrinsic valuation satisfies $\mu^d = \frac{p_d - \beta f_d}{\theta}$ derive zero utility when buying from the online channel. As mentioned, consumers' channel selection of buying depends on which channel they can derive more utility. Thus, if $V_r + \beta f_r - p_r \ge V_d + \beta f_d - p_d$, then consumers prefer the retail channel to the online channel. Similarly, if $V_r + \beta f_r - p_r < V_d + \beta f_d - p_d$, then the online channel is preferred to the retail channel. Thus consumers whose intrinsic valuation μ^{dr} equals $\frac{p_r - p_d + \beta f_d - \beta f_r}{1 - \theta}$ will select the two channels indifferently and if the intrinsic valuation exceeds this value, they prefer the retail channel. It is easy to find that when $\mu^d < \mu^r$, then $\mu^d < \mu^r < \mu^{dr}$, and when $\mu^d > \mu^r$, then $\mu^{dr} < \mu^d < \mu^r$. In the former situation, all consumers with intrinsic valuations in the interval $[\mu^d, \mu^{dr}]$ may purchase through the online channel, and all consumers with intrinsic valuations in the interval $[\mu^{dr}, 1]$ may purchase through the retail channel. Consumers whose intrinsic

[1] In our paper, the consumer's utility βf_i derived from returns policy is independent of the consumer valuation V_i; it only refers to the value that the consumer perceives from the return refund, and V_i refers to the prior valuation on the product itself regardless of the returns policy. So β is an individual variable to measure customer's sensitivity to returns policy.

[2] Perfectly rational consumers are a common assumption in many economic and managerial literature. When consumers are perfectly rational, they systematically and purposefully do the best they can to achieve their objectives. As consumers, they maximize utility.

Table 1
Demand functions and objective functions in two scenarios.

	FR-RN	FR-RA
Demand Functions	$Q_r = \begin{cases} 1 - \frac{p_r - p_d + \beta f_d - \beta f_r}{1-\theta}, & \frac{p_d - \beta f_d}{\theta} \le p_r - \beta f_r \\ 1 - p_r + \beta f_r, & otherwise \end{cases}$	$\tilde{Q}_r = Q_r + \varepsilon$
	$Q_d = \begin{cases} \frac{\theta p_r - p_d + \beta f_d - \theta\beta f_r}{\theta(1-\theta)}, & \frac{p_d - \beta f_d}{\theta} \le p_r - \beta f_r \\ 0, & otherwise \end{cases}$	$\tilde{Q}_d = Q_d + \varepsilon$
Objective Functions	$\pi_s = wQ_r + p_d \cdot (1-\alpha_d)Q_d + (p_d - f_d + s)\cdot \alpha_d Q_d$	$E(\tilde{\pi}_s) = wQ_r + p_d \cdot (1-\alpha_d)Q_d + (p_d - f_d + s)\cdot \alpha_d Q_d$
	$\pi_r = p_r \cdot (1-\alpha_r)Q_r - wQ_r + (p_r - f_r + s)\cdot \alpha_r Q_r$	$U(\tilde{\pi}_r) = E(\tilde{\pi}_r) - k\sqrt{Var(\tilde{\pi}_r)} = [p_r \cdot (1-\alpha_r) - w + s\alpha_r](Q_r - k\sigma)$

Note. When $\frac{p_d - \beta f_d}{\theta} \le p_r - \beta f_r$, demands exist in both channels of the supply chain. So, this paper only focuses on the feasible region of the coexisting dual-channel supply chain.

Table 2
The equilibrium results in two scenarios.

FR-RN	FR-RA
$w^* = \frac{1-\alpha_r}{2}\cdot\frac{1-\theta}{1-\beta} + \frac{2-\alpha_r-\alpha_d}{2}\cdot\frac{B}{A} + \frac{\alpha_r+\alpha_d}{2}s$	$\tilde{w}^* = \frac{1-\alpha_r}{2}\cdot\frac{1-\theta}{1-\beta} + \frac{2-\alpha_r-\alpha_d}{2}\cdot\frac{B+\Delta}{A} + \frac{(\alpha_r+\alpha_d)s}{2} + \Delta_1$
$p_r^* = \frac{3}{4}\cdot\frac{1-\theta}{1-\beta} + \frac{4-3\alpha_r-\alpha_d}{4(1-\alpha_r)}\cdot\frac{B}{A} + \frac{\alpha_d-\alpha_r}{4(1-\alpha_r)}s$	$\tilde{p}_r^* = \frac{3}{4}\cdot\frac{1-\theta}{1-\beta} + \frac{4-3\alpha_r-\alpha_d}{4(1-\alpha_r)}\cdot\frac{B+\Delta}{A} + \frac{(\alpha_d-\alpha_r)s}{4(1-\alpha_r)} - \Delta_2$
$p_d^* = \frac{B}{A}$	$\tilde{p}_d^* = \frac{B+\Delta}{A}$

Where , $A = \frac{D}{4\theta(1-\alpha_r)}$, $B = \frac{1-\theta}{1-\beta}\cdot\frac{4-3\alpha_d-\alpha_r}{4} + (1-\frac{2}{\theta})\cdot\frac{s\alpha_d}{2} + \frac{2\alpha_d-\alpha_r^2-\alpha_d^2}{4(1-\alpha_r)}s$.
$D = 4(1-\alpha_r)(1-\alpha_d)(2-\theta) - \theta(2-\alpha_r-\alpha_d)^2$, $\Delta_1 = \frac{k\sigma(1-\alpha_r)}{2(1-\beta)}$, and $\Delta_2 = \frac{k\sigma}{4(1-\beta)}$, $\Delta = \frac{k\sigma(\alpha_d-\alpha_r)}{4(1-\beta)}$.

valuation are in $[0, \mu^d]$ will leave the market. In the latter situation, only consumers with intrinsic valuation in the interval $[\mu^r, 1]$ may purchase through the retail channel. Therefore, the demand functions in the retail channel and the online channel are derived and given in the Table 1.

In addition, empirical studies (e.g., Hess and Mayhew, 1997) and other researches (e.g., Bonifield et al., 2010; Chen and Bell, 2012; Chen and Chen, 2016) have shown that the amount of returned products has a strong positive linear relationship with the sold quantity. Thus we assume that both channels face the amount of consumer returns which are proportional to the sales with the return rates $\alpha_i, i = r, d$. Moreover, Rao et al. (2014) point out that returns happened in the online channel more frequently than those in the retail channel, then we further assume $0 < \alpha_r \le \alpha_d < 1$. For convenience, operational costs of both online channel and the retail channel are considered as zero. And to simplify the exposition, the marginal handling costs of returned products $c_i(i = r, d)$ are supposed as zero without influencing the basic results (Pei and Yan, 2015).

Then, the profit of the supplier is

$$\pi_s = wQ_r + p_d \cdot (1-\alpha_d)Q_d + (p_d - f_d + s)\cdot \alpha_d Q_d.$$

Where the first corresponds to the supplier's revenue sold to the retailer. The second comes from the products sold at his online channel, but not returned by consumers. The third represents the products sold at his online channel but returned by consumers.

Similarly, the retailers profit is given as follows:

$$\pi_r = p_r \cdot (1-\alpha_r)Q_r - wQ_r + (p_r - f_r + s)\cdot \alpha_r Q_r.$$

Here, we assume that the supplier will not buy back the products returned by consumers in the retail channel (Liu and Xiao, 2008).

3.3. Full returns policy with a risk-neutral manufacturer and a risk-averse retailer

Supplier encroachment carves up the retailers' original demands. Meanwhile, offering returns policy can remedy the disadvantages of online channels such as purchase uncertainty. All of these may bring greater pressure for retailers. Especially when the market demand is uncertain, the retailer may possess the risk-averse behavior. In this subsection, we assume the retailer has risk-averse behavior and therefore we label this scenario as FR-RA (FR is for Full Returns policy and RN is for Risk-Averse). All notations are defined as in the scenario FR-RN. The mean-variance method is used to evaluate the risk-averse retailer's expected utility as follows (Lau, 1980):

$$U(\pi_r) = E(\pi_r) - k\sqrt{Var(\pi_r)},$$

where k is the degree of the retailer's risk aversion. $k = 0$ denotes that the retailer is risk-neutral, and $k > 0$ means that the retailer is risk-averse.

Following Dumrongsiri et al. (2008) and Yan et al. (2016), the stochastic demands are assumed that $\tilde{Q}_r = Q_r + \varepsilon$ and $\tilde{Q}_d = Q_d + \varepsilon$ in both channels, where ε is a random variable and follows Gaussian distributions, that is, $\varepsilon \sim N(0, \sigma^2)$. The expected profit of the supplier and the expected utility of the retailer are shown in the Table 1. Then we obtain the equilibrium outcomes in two scenarios and the results are listed in the Table 2. The proofs are given in Appendix A.

4. Model analysis

From Table 1, we can find that all the equilibrium solutions of the scenario FR-RA are closely related with the parameter $k\sigma$. Here define $\eta = k\sigma$, then it denotes the retailer's degree of perceived risk aversion derived from the demand fluctuation. That is, when the demand fluctuation increases, the retailer's risk-averse degree will increase, and vice versa.

Next,based on the equilibrium outcomes of the supplier and the retailer in the scenarios FR-RN and FR-RA, we can analysis how returns policy influences two members' strategies in the supply chain, the consumers demands through a comparison between the two scenarios.

Proposition 1. *When both channels provide the full returns policy. Given* η *, with regard to the consumer sensitivity* β *to the returns policy, the* *properties are satisfied as follows:*

(i) *The wholesale prices and the online prices will increase with the increase of β under the scenarios FR-RN and FR-RA.*
(ii) *The retail price will rise up under the scenario FR-RN, when β increases; but under the scenario FR-RA, the retail price may rise up or fall down. Exactly, there exists a parameter $\theta_k \in (0, 1)$, if $0 < \theta \le \theta_k$, then the retail price will increase. If $\theta_k < \theta < 1$, then there also exists a parameter $\hat{\eta} \in (0, 1)$, when $0 \le \eta \le \hat{\eta}$, the retail price will rise up; when $\hat{\eta} < \eta \le 1$, the retail price will fall down.*

The proofs of Proposition 1 are given in Appendix B.

For the retailer, when both members are risk-neutral, the retail price will increase with the consumer sensitivity β to the returns policy. This is because providing returns policy increases consumers' reference utility in the deal. Returns policy mitigates the perceived risk of product misfits, thus consumers have more confidence in buying the product. Under a given price, the increase of the consumer's reference utility definitely leads to the increased utility. A higher sensitivity to returns policy implies higher recognition of the returns policy and a higher level of willingness to pay. Thus consumers have more incentive to buy products. Note that when $\beta = 0$ means that the consumers don't care about returns policy before purchase and therefore returns policy has little or no impact on consumers' purchase decision. As the price-setter, the retailer accounting for consumers' behavioral motives will enhance the retail price to increase profit margin and squeeze more consumer surplus.

However, when the market demand is stochastic and the retailer has risk-averse behavior, the impact of β is related to her risk-averse level and the consumer acceptance for the online channel. When the consumer acceptance of the online channel is relatively low (i.e., $\theta \le \theta_k$), the demand in the retail channel is relatively high. This mitigates the retailer's concerns for her low profits. Although the retailer has risk-averse behavior, with the increase of consumers' sensitivity to returns policy, consumer utility in the retail channel becomes higher, thus consumers have a stronger desire to consume the product from the retailer. Therefore, with the increase of consumer sensitivity β to the returns policy, the retailer will set a higher optimal price in the retail channel. Yet, when the consumer acceptance for the online channel is relatively high (i.e., $\theta > \theta_k$), the market share in the retail channel shrinks. If the retailer has the low level of risk aversion attitude (i.e., $0 \le \eta \le \hat{\eta}$), then there is little impact on the risk-averse retailer's pricing policy under such adverse situation. Thus, the optimal price in the retail channel will also increase in consumers' sensitivity to the returns policy. However, as the retailer's level of risk aversion increases (i.e., $\hat{\eta} < \eta \le 1$), the retailer's perspective risk-averse attitude caused by demand fluctuations leads to a conservative strategy. As mentioned before, risk aversion amplifies the retailer's concern for low profits, which is associated with low realizations of the random demand. Even though the consumers' higher sensitivity means more potential demand, such trend cannot offset the concern of a high risk-averse retailer. Therefore, it is surprising that the retailer will deviate from the original preferences about her retail pricing when the retailer has a high level of risk aversion attitude. This interesting result indicates that the extremely high level of risk aversion has greater influence on the retailer's pricing strategy than the effect of stimulated by the returns policy.

For the supplier, in the scenarios FR-RN and FR-RA, both of the optimal online prices are monotonously increasing in consumers' sensitivity to returns policy. That is, the effect of returns policy stimulates the increase of the online price. At the same time, the supplier knows that the retailer will increase her selling price in the retail channel, so he will charge a higher wholesale price to maximize his own profit. These manifest that the retailer's risk-averse level doesn't change the impact of β on supplier's optimal strategies.

Next, we will explore how consumers' sensitivity to returns policy influences the channels demand.

Proposition 2. *In the scenarios FR-RN and FR-RA, when both channels provide the full returns policy, the demands in the retail channel increases with the consumer's sensitivity to returns policy. However, the demands in the online channel and the total demands in the supply chain decrease with consumer's sensitivity to returns policy.*

The proofs are given in Appendix C.

Proposition 2 reveals an important and interesting result. In the retail channel, consumers are able to observe and inspect the products before making their purchasing decisions. When the retailer provides a full returns policy, consumers are given more guarantees to product misfits besides the inspection and experience in stores. Thus given the retail price, consumers with higher β have higher utility, definitely, they have more willingness to buy the product in the retail chain. Although the higher β implies a higher retail price, the online price possesses a faster growth with the increase of β compared with the retail price. As a result, the demand in the retail channel increases with β.

However, it is surprising to find that the higher β has a negative effect on the demand in the online channel. The rationale behind such phenomenon is that the online demand is mainly affected by the retail price and the online price. The higher sensitivity to returns policy leads to higher prices. Compared with the traditional channel, if the consumers purchase through the online channel, then they will exert extra perceived risk. For example, when buying products like clothing online, consumers are difficult to confirm the right color or size because of lacking fitting. Davis et al. (1995) and Dai et al. (2014) comment that when consumers are vague about the benefits from a product, they are less willing to purchase the product until they confirm that the product would meet their requirements. Although providing the full returns policy in the online channel could reduce consumers' uncertainty about product features, for the consumers, the impact of the online price is greater than that of the retail price. Therefore, the demand of the online channel will decrease with β.

At the same time, the total demand decreases with the consumer's sensitivity to returns policy. From the demand function, we can see that the retail price's elasticity coefficient in the retail channel equals to its cross-price sensitivity in the online channel. Thus each unit increase in the retail price is associated with equal amount of transfer from the retail channel to the online channel. While the online price's elasticity coefficient in the online channel is larger than its cross-price sensitivity in the retail channel. Thus each unit increase in the online price results in that the loss of customers from the online channel are not completely transferred into the retail channel. This explains why the total demand decreases with consumer's sensitivity to returns policy. Proposition 2 also shows that when the retailer has risk-averse behavior, the above results still hold true.

Proposition 3. *When both channels provide the full returns policy. Given β, there are some properties as follows:*

(i) *For the retailer, the retail price decreases with the degree of the retailer's perceived risk aversion level (i.e., $\partial\tilde{p}_r{}^*/\partial\eta < 0$).*
(ii) *For the supplier, both the online price and the wholesale price increase with the degree of the retailer's perceived risk aversion level (i.e., $\partial\tilde{p}_d{}^*/\partial\eta > 0$ and $\partial\tilde{w}^*/\partial\eta > 0$).*
(iii) *The expected demand in the retail channel increases with the degree of the retailer's perceived risk aversion level (i.e., $\partial E(\tilde{Q}^*{}_r)/\partial\eta > 0$), the online channel demand and the expected total demand decrease with the degree of the retailer's perceived risk aversion level (i.e., $\partial E(\tilde{Q}^*{}_d)/\partial\eta < 0$ and $\partial E(\tilde{Q}^*{}_t)/\partial\eta < 0$).*

The proofs are given in Appendix D. Proposition 3 implies that the members' optimal decisions are influenced when the retailer has risk-averse behavior. Different from the results in the Proposition 1, no matter how sensitive consumers are to returns policy, for a given β, the retailer's optimal retail price always decreases with the degree of the retailer's perceived risk aversion level. This is because the risk-averse behavior amplifies the retailer's concerns for low profit, which is associated with both the realizations of the random demand and the selling price in the retail channel. So the retailer will stimulate the demand by reducing the selling price to increase the profit when she has serious risk aversion.

Meanwhile, for the supplier, his optimal online price and his wholesale price increase with η. The reason may be that compared with the conservative retailer with risk-averse behavior, the risk-neural supplier actively faces the demand to achieve the more marginal profit through keeping the higher price, and the more serious the retailer's risk aversion is, the higher the supplier's pricing decisions are made in contrast. As a result, the expected demands in the retail and the online channel are increasing and decreasing with η respectively. Similar with Proposition 2, the amount of consumers lost in the online channel is more than the amount of new entrants in the retail channel, so the total demand decreases with the degree of the retailer's perceived risk aversion level.

Proposition 4. *When both channels provide the full returns policy.*

(i) *For the retailer, the selling price in the retail channel is lower compared with that under the risk-neural case (i.e.,* $\tilde{p}_r^* < p_r^*$*).*

(ii) *For the supplier, both the online price and the wholesale price are higher compared with that under the risk-neural case (i.e.,* $\tilde{p}_d^* > p_d^*$ *and* $\tilde{w}^* > w^*$*).*

(iii) *The expected demand in the retail channel is higher in scenario FR-RA (i.e.,* $E(\tilde{Q}^*_r) > Q_r^*$*), the expected demand in the online channel and the expected total demand are lower in scenario FR-RA (i.e.,* $E(\tilde{Q}^*_d) < Q_d^*$, $E(\tilde{Q}^*_t) < Q_t^*$*).*

The proofs are given in Appendix E. From Proposition 4 (i) and (ii), we can see that when the retailer has risk-averse behavior, the cannibalization effect between dual channels is more furious. According to Proposition 3, the retailer will reduce the retail price and the supplier will increase the online price compared with the FR-RN scenario. As the price is the most dominant driver for the demand, the change in price directly influences consumers' surplus. Consumers will exploit the price differences by shifting demand from a low surplus channel to a high surplus channel. As a result, more purchase happens in the retail channel, yet some demand in the online channel runs off. But, the total demand also shrinks. This phenomenon indicates that the declining demand of the online channel plays a decisive role in the seesaw battle.

Because we cannot explicitly analyze the profit and the utility of the members in the scenarios FR-RN and FR-RA, the following part will explore how the consumers' sensitivity to returns policy and the retailer's perceived risk aversion level affect the members' performance by the experiments, and further mine the important insights. Assume that $\alpha_r = 0.3$, $\alpha_d = 0.4$, $s = 0.2$, $\theta_r = 0.8$. These parameters are set up based on the literature. For example, α_r and α_d are set up based on Chen and Bell (2012), s is set up based on Yue and Liu (2006) and θ is set up based on Li and Hou et al. (2017).

Figs. 1 and 2 illustrate both members' performances under the scenarios FR-RN and FR-RA. Where $\eta = 0$ represents the scenario FR-RN and $\eta > 0$ represents the scenario FR-RA with different levels of the retailer's perceived risk aversion. From Figs. 1 and 2, we can observe that both members' performances increase in the consumers' sensitivity β to returns policy in both scenarios FR-RN and FR-RA. Providing full returns policy not only increases consumers' utility but also benefits the downside retailer and the encroaching supplier. This finding indicated that providing full returns policy for consumers will bring benefit to both the retailer and the supplier. The higher of consumers' sensitivity β to returns policy is, the greater the benefit they can obtain. In addition, Figs. 1 and 2 also show that an increased risk aversion level may lead to a smaller expect utility for the retailer while a larger profit for the supplier.

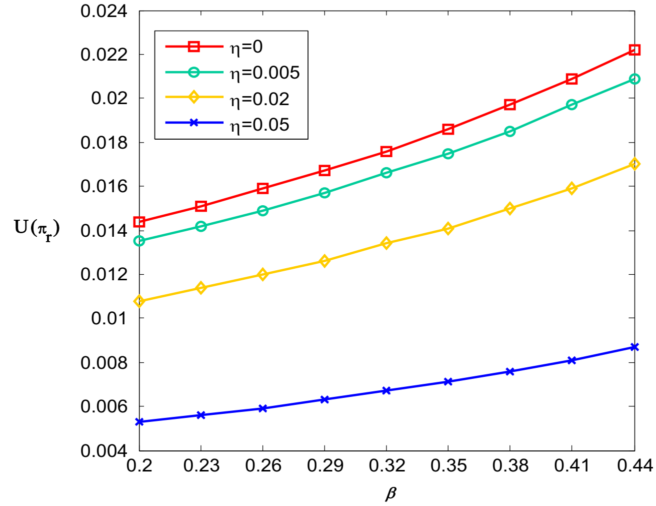

Fig. 1. Impacts of β on the retailer's expected utility under different risk factors.

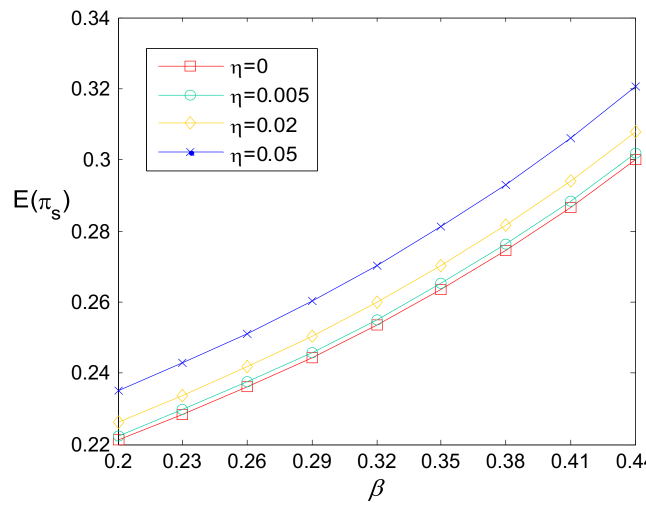

Fig. 2. Impacts of β on the supplier's expected profit under different risk factors.

5. Extensions

In this section, we discuss the supply chain coordination and the market competition problem.

5.1. Supply chain coordination under supplier encroachment

Supply chain coordination problem has important implications. In this section, we design a contract to coordinate the supply chain under the supplier encroachment when both members are risk-neutral. Several literature has studied the coordination problem for supply chains under supplier encroachment such as Cai (2010), Chen et al. (2012) and Li et al. (2016). Two conditions should be satisfied if the supply chain is coordinated. The first condition is that the total profit of the supply chain under the contract is equal to that in the centralized supply chain. The second condition is that each member's profit under the contract cannot be less than that in the decentralized situation.

In the centralized situation, the profit of the centralized supply chain is as follows:

$$\tilde{\pi}_{SC} = \tilde{\pi}_r + \tilde{\pi}_s,$$
$$E[\tilde{\pi}_{SC}] = [p_r^c(1-\alpha_r) + s\alpha_r]Q_r + [p_d^c(1-\alpha_d) + s\alpha_d]Q_d.$$

The optimal solutions (p_r^{c*}, p_d^{c*}) in the centralized supply chain are given in the Appendix F.

Next, we use a two-part tariff contract (w^t, F^t) to coordinate the supply chain. The reason why we choose this contract to coordinate the supply chain can be explained as follows. Yan and Zaric (2016) suggest that different contracts have different levels of efficiency (which is defined as the required number of parameters in the contract), flexibility (which is defined as the range of choices for the wholesale price), and required information for coordination. From the contract, we can see that the two-part tariff contract (w^t, F^t) has high efficiency, high flexibility and need less information. Such characteristics ensure the success of the negotiation and the convenience of the contract implementation. Therefore, we choose this contract to coordinate the supply chain. The supplier first offers a wholesale price w^t and then charges a lump sum fee F^t from the retailer for payment. The objective functions of the supplier and the retailer under the two-part tariff contract are as follows:

$$E[\tilde{\pi}_s^t] = w^t Q_r + [p_d^t(1-\alpha_d) + s\alpha_d]Q_d + F^t,$$
$$E[\tilde{\pi}_r^t] = [p_r^t(1-\alpha_r) - w^t + s\alpha_r]Q_r - F^t.$$

When a contract can coordinate the supply chain, it makes sure that the optimal product prices in both channels under the contract are equal to those prices in the centralized supply chain. And the following Proposition describes the contract that can coordinate the decentralized supply chain.

Proposition 5. *If the contract parameters* (w^t, F^t) *satisfy the following conditions:*

$$w^t = w^{t*} \text{ and } F^t \in [F_1^t, F_2^t],$$

then the two-part tariff contract can coordinate the supply chain with the risk-averse retailer under supplier encroachment.

w^{t*}, F_1^t, F_2^t and the proofs are given in Appendix F.

Next, we use the numerical experiments to illustrate the effect of two-part tariff contract on members' Pareto improvements. Assume that $\alpha_r = 0.1$, $\alpha_d = 0.2$, $s = 0.1$, $\theta_r = 0.8$, $\beta = 0.6$. From Fig. 3, we can see both the supplier and retailer yield higher profits under the two-part tariff contract. To ensure both the supplier and the retailer will participate in the coordination, the lump sum fee F^t should be in a reasonable range, i.e. $F^t \in [F_1^t, F_2^t]$. The sum of the supplier's and the retailer's profit in the coordination is equal to the supply chain's profit in the centralized situation. At the same time, we know that the wholesale price in the decentralized supply chain is $w = 1.1114$ and the wholesale price in the coordination is $w^t = 0.8707$. The retailer's optimal retail price in the decentralized supply chain is $p_r = 1.37448$ and is $p_r^t = 1.2598$ in the coordination. The supplier charges a lower wholesale price in the coordination and this incents the retailer to set a lower retail price, which increases the demand in the retail channel. This implies that the potential conflict generated by supplier encroachment is mitigated by the two-part tariff contract to some degree.

5.2. Market competition

Competitive markets are more commonly seen in reality, thus in this section, we consider the case when the market is competitive. First, we assume the market has multiple homogeneous retailers and analyze the impacts of retailer competition. Then, we analyze the situation when the market has multiple homogeneous suppliers.

We assume that in the supplier's traditional channel, there are n homogeneous retailers. These retailers are totally independent and compete with each other on the market. In line with Section 3, the supplier as the Stackelberg leader first decides $\hat{w}$ and $\hat{p}_d$, and then retailers decide the retail price $\hat{p}_{ri}$ simultaneously after observing the supplier's decision. At the same time, all channels provide the full returns policy for consumer to return the product they are not satisfied.

When consumers buy the product from the online channel, their utility is $\theta\mu + \beta\hat{f}_d - \hat{p}_d$. And consumers' utility is $\mu + \beta\hat{f}_{ri} - \hat{p}_{ri}$ if they purchase from the retailer i. Because the retailers are homogeneous and fully substitutable, this means that consumers firstly choose purchase channel based on utility comparison and those consumers who chose the traditional channel are evenly distributed to each retailer to make the final purchase. So the demand and the retail price in the traditional channel for all retailers is the same, i.e. $\hat{p}_{r1} = ...=\hat{p}_{ri} = ...=\hat{p}_{rn} = \hat{p}_r$, $\hat{Q}_{r1} = ...=\hat{Q}_{ri} = ...=\hat{Q}_{rn}$.

The basic demand in each retail channel and the online channel are as follows:

$$\hat{Q}_{ri} = \frac{\hat{Q}_R}{n} = \frac{1}{n}[1 - \frac{(1-\beta)(\hat{p}_r - \hat{p}_d)}{1-\theta}],$$
$$\hat{Q}_d = \frac{(1-\beta)(\theta\hat{p}_r - \hat{p}_d)}{\theta(1-\theta)}.$$

The stochastic demands are $\tilde{\hat{Q}}_{ri} = \frac{\hat{Q}_R + \varepsilon}{n}$ and $\tilde{\hat{Q}}_d = \hat{Q}_d + \varepsilon$ in each retail channel and the online channel. Then in Table 3, we give members' objective functions.

From Table 3, we find that the number of retailers does not affect the optimal decisions, i.e. $\hat{w}^* = \tilde{w}^*$, $\hat{p}_r^* = \tilde{p}_r^*$, $\hat{p}_d^* = \tilde{p}_d^*$. n only affects the competitive retailers' expected utility. The more retailers, the less utility each retailer obtains. However, the expected profit of the supplier remains the same compared with the single retailer situation.

Similarly, when the market has n homogeneous suppliers and one

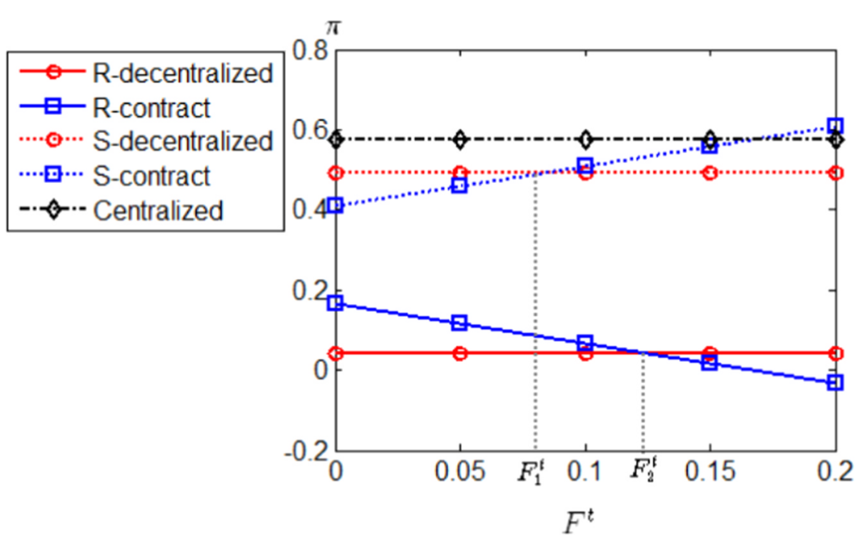

Fig. 3. Coordination of the supply chain by using the two-part tariff contract.

Table 3
Objective functions with multiple retailers.

member	objective function
Profit of the supplier	$\hat{\pi}_s = w\tilde{\hat{Q}}_R + \hat{p}_d\cdot(1-\alpha_d)\tilde{\hat{Q}}_d + (\hat{p}_d - \hat{f}_d + s)\cdot\alpha_d\tilde{\hat{Q}}_d$
Profit of the retailer i	$\hat{\pi}_{ri} = \hat{p}_r\cdot(1-\alpha_r)\tilde{\hat{Q}}_{ri} - w\tilde{\hat{Q}}_{ri} + (\hat{p}_r - \hat{f}_r + s)\cdot\alpha_r\tilde{\hat{Q}}_{ri}$
Supplier's expected profit	$E(\hat{\pi}_s) = \hat{w}\hat{Q}_R + \hat{p}_d(1-\alpha_d)\hat{Q}_d + s\alpha_d\hat{Q}_d$
Retailer i's expected utility	$U(\hat{\pi}_{ri}) = [\hat{p}_{ri}(1-\alpha_r) - \hat{w} + s\alpha_r](\hat{Q}_R - \eta)/n$

retailer, consumers still firstly choose purchase channel based on utility comparison. As all suppliers are totally independent and homogeneous, in the end, we obtain, $\hat{p}_{r1} = ...=\hat{p}_{ri} = ...=\hat{p}_{rn} = \hat{p}_r$, $\hat{p}_{d1} = ...=\hat{p}_{di} = ...=\hat{p}_{dn} = \hat{p}_d\hat{Q}_{r1} = ...=\hat{Q}_{ri} = ...=\hat{Q}_{rn}$, $\hat{Q}_{d1} = ...=\hat{Q}_{di} = ...=\hat{Q}_{dn}$. Therefore, the basic demand in each retail channel and each online channel are as follows:

$$\hat{Q}_{ri} = \frac{\hat{Q}_R}{n} = \frac{1}{n}\left[1 - \frac{(1-\beta)(\hat{p}_r - \hat{p}_d)}{1-\theta}\right],$$
$$\hat{Q}_d = \frac{\hat{Q}_d}{n} = \frac{1}{n}\left[\frac{(1-\beta)(\theta\hat{p}_r - \hat{p}_d)}{\theta(1-\theta)}\right].$$

Apparently, we can see that when the market has multiple suppliers, the optimal decisions remain consistent with our basic model (i.e. single supplier with single retailer). At this time, n affects both the suppliers' expect profit and the retailer' expected utility. All members obtain a fraction of the profit compared with the non-competitive situation. The more suppliers, the less profit each member obtains.

6. Conclusions

In this paper, a supplier distributes his products through a dual-channel competitive market. Because returns policy as an important customer service, can reduce the likelihood of misfit risk and influence consumers' expected utility surplus, we assume that both the retail and online channels provide consumer returns service. Thus, returns policy positively affects consumers' utility and purchase intention. First, we build two scenarios (FR-RN and FR-RA) based on the retailer's different risk attitude and derive the equilibrium solutions in both scenarios. Next we examine how the consumers' sensitivity to returns policy impacts pricing strategies and both channel demands in each scenario. By using MV criterion, we can evaluate the impacts of risk aversion level on cannibalization effect in the scenario FR-RA. We further compare the two scenarios with respect to pricing strategies and channel demands and examine members' performance by a numerical study. Besides, we also investigate the supply chain coordination problem and the market competition problem.

7. Managerial implications and limitations

Our results provide the valuable managerial implications for business managers. The most significant contribution is that our paper analytically integrates the effect of consumer returns policy into consumer purchase intention and investigates how consumers' sensitivity to returns policy affects the pricing strategy, the market demand and supply chain members' performance. First, this paper proposes a valuable guideline on pricing setting for both supplier and the retailer. By identifying consumers' sensitivity to return policies, the supplier and the retailer could set prices correspondingly. For both the supplier and the retailer, if they face consumers that are more sensitive to returns policy, they should increase the selling price because these consumers are able to accept a higher price. On the contrary, if the consumers are not very sensitive to returns policy, both the supplier and the retailer should decrease the selling price. Adjusting the price appropriately can help members make higher profits. Therefore, knowing how consumers value returns policy is of significant for both the supplier and the retailer. Shang et al. (2017) analyze the return policy value from the consumer's perspective. Their work provides a way to explore how consumers value product return policies in retail. Second, it is worth noting that the retailer cannot always follow such pricing strategy when she has risk-averse behavior. The fluctuating market demand and channel conflict bring double pressure on the retailer and thus affects risk-averse retailer's pricing strategy. When the product is highly accepted in the online channel, an increasing consumers' sensitivity to returns policy will lead to the decrease of the retail price when the retailer has an extremely high risk-averse level. Therefore, the retailer should pay special attention to products with higher online channel acceptance, such as books, electronics. Luo and Sun (2016) use an empirical study to elicit consumers' willingness-to-pay for purchasing a product from a traditional channel vs. an online channel. They comprise a variety of product categories including apparel, consumer electronics, furniture, home appliances, jewelry, and books. The supplier and the retailer can apply a similar approach to identify consumer's online channel acceptance of a certain product category and establish reasonable price policy respectively. Furthermore, even though the cannibalization effect is more furious when the market demand is uncertain and the retailer has risk-averse behavior, our research reveals valuable implications for supply chain members who are concerned about the channel conflict. Based on our findings, both the retailer and the supplier will benefit from providing full returns policy for consumers especially when consumers' sensitivity to returns policy is high.

This paper has some limitations and thus we can extend in several ways. First, future research can involve consumer's behavior and characteristics in the model, such as consumer trust, brand loyalty and consumer's purchase experience and investigate how consumer's behavior and characteristics affect their channel choices as well as their purchase decisions. Second, this paper only considers the situation in which the retailer has risk-averse behavior, it may also be interesting to investigate the situations that both agents have risk-averse behavior in a dual-channel supply chain. Third, in our study, although we use the refund amount as the characteristic of the returns policy, consumer returns policy can differ in other dimensions such as duration of the return and hassle cost of the return. Thus future research can be extended to examine these dimensions and how these elements affect the way consumers access the returns policy. Finally, we can continue to investigate the role of competition such as the retailer is multi-brand and could sell different product categories.

Acknowledgements

The authors are grateful to the editor and the two anonymous reviewers for theirvaluable and constructive comments. This work is supported by the National Natural Science Foundation of China under Grant Nos. 71472133 and 71602045. And is also supported by Humanity and Social Science Youth Foundation of Education of China No. 16YJCZH077 (2016.7-2019.6).

Appendix A

Proof of equilibrium results in scenarios FR-RN and FR-RA.

First we solve the equilibrium results in the scenario FR-RN.

Because both channels offer full returns policy, thus we have $f_r = p_r$ and $f_d = p_d$. The demand functions and retailer's profit function are as follows:

$$Q_r = 1 - \frac{(1-\beta)(p_r - p_d)}{1-\theta},\ Q_d = \frac{(1-\beta)(\theta p_r - p_d)}{\theta(1-\theta)},\ \pi_r = [p_r(1-\alpha_r) - w + s\alpha_r]Q_r.$$

Using the backward induction, the retailer decides her selling price given w and p_d. The first-order and second-order derivatives with respect to p_r are as follows:

$$\frac{\partial \pi_r}{\partial p_r} = 1 - \alpha_r - \frac{2(1-\beta)(1-\alpha_r)}{1-\theta}p_r + \frac{(1-\beta)(1-\alpha_r)}{1-\theta}p_d + (w - s\alpha_r)\frac{1-\beta}{1-\theta},$$
$$\frac{\partial^2 \pi_r}{\partial {p_r}^2} = -\frac{2(1-\beta)(1-\alpha_r)}{1-\theta}.$$

Then we derive $p_r = \frac{1}{2}(\frac{1-\theta}{1-\beta} + p_d + \frac{w - s\alpha_r}{1-\alpha_r})$. Accordingly, the supplier's profit is

$$\pi_s = w\left[\frac{1}{2} + \frac{1-\beta}{2(1-\theta)}p_d - \frac{(1-\beta)(w-s\alpha_r)}{2(1-\theta)(1-\alpha_r)}\right] + [p_d(1-\alpha_d) + s\alpha_d]\left[\frac{1}{2} + \frac{(\theta-2)(1-\beta)}{2\theta(1-\theta)}p_d + \frac{(1-\beta)(w-s\alpha_r)}{2(1-\theta)(1-\alpha_r)}\right].$$

The Hessian matrix of π_s is as follows:

$$H = \begin{bmatrix} -\frac{(1-\beta)}{(1-\theta)(1-\alpha_r)} & \frac{1-\beta}{2(1-\theta)} + \frac{(1-\beta)(1-\alpha_d)}{2(1-\theta)(1-\alpha_r)} \\ \frac{1-\beta}{2(1-\theta)} + \frac{(1-\beta)(1-\alpha_d)}{2(1-\theta)(1-\alpha_r)} & -\frac{(1-\alpha_d)(2-\theta)(1-\beta)}{\theta(1-\theta)} \end{bmatrix}.$$

Denote d_1 and d_2 as the first-order and second-order principal minor determinants. Thus, we have

$$d_1 = -\frac{(1-\beta)}{(1-\theta)(1-\alpha_r)} < 0,$$
$$d_2 = \frac{(1-\beta)^2}{4\theta(1-\alpha_r)^2(1-\theta)^2}\cdot[4(1-\alpha_r)(1-\alpha_d)(2-\theta) - \theta(2-\alpha_r-\alpha_d)^2].$$

Let $D = 4(1-\alpha_r)(1-\alpha_d)(2-\theta) - \theta(2-\alpha_r-\alpha_d)^2$. When $D > 0$, there is

$$8\theta(1-\alpha_r-\alpha_d+\alpha_r\alpha_d) + \theta(\alpha_r-\alpha_d)^2 \le 8(1-\alpha_r-\alpha_d+\alpha_r\alpha_d).$$

According to Chebyshev inequality, one can derive $1-\alpha_r-\alpha_d+\alpha_r\alpha_d \ge 0$, thus we have $\theta < \frac{8(1-\alpha_r-\alpha_d+\alpha_r\alpha_d)}{8(1-\alpha_r-\alpha_d+\alpha_r\alpha_d)+(\alpha_r-\alpha_d)^2} \le 1$. Let $\bar{\theta} = \frac{8(1-\alpha_r-\alpha_d+\alpha_r\alpha_d)}{8(1-\alpha_r-\alpha_d+\alpha_r\alpha_d)+(\alpha_r-\alpha_d)^2}$, then when $\theta < \bar{\theta}$, the Hessian matrix is negative definite and π_s is joint concave in $p_d{}^*$ and w^*.

From the first-order derivatives of π_s, the supplier's optimal decisions are $p_d{}^* = \frac{B}{A}$ and $w^* = \frac{(1-\theta)(1-\alpha_r)}{2(1-\beta)} + \frac{2-\alpha_r-\alpha_d}{2}\cdot\frac{B}{A} + \frac{(\alpha_r+\alpha_d)s}{2} > 0$, where $A = \frac{D}{4\theta(1-\alpha_r)}$ and $B = \frac{1-\theta}{1-\beta}\cdot\frac{4-3\alpha_d-\alpha_r}{4} + (1-\frac{2}{\theta})\cdot\frac{s\alpha_d}{2} + \frac{(2\alpha_d-\alpha_r^2-\alpha_d^2)\cdot s}{4(1-\alpha_r)}$. By substituting $p_d{}^*$ and w^* into (A.1), we obtain $p_r{}^* = \frac{3(1-\theta)}{4(1-\beta)} + \frac{4-3\alpha_r-\alpha_d}{4(1-\alpha_r)}\cdot\frac{B}{A} + \frac{\alpha_d-\alpha_r}{4(1-\alpha_r)}s$.

Using the same method, we obtain the equilibrium solutions in the scenario FR-RA as follows:

$$\tilde{p}_d{}^* = \frac{B+\Delta}{A},$$
$$\tilde{w}^* = \frac{(1-\theta)(1-\alpha_r)}{2(1-\beta)} + \frac{2-\alpha_r-\alpha_d}{2}\cdot\frac{B+\Delta}{A} + \frac{(\alpha_r+\alpha_d)s}{2} + \Delta_1$$
$$\tilde{p}_r{}^* = \frac{3(1-\theta)}{4(1-\beta)} + \frac{4-3\alpha_r-\alpha_d}{4(1-\alpha_r)}\cdot\frac{B+\Delta}{A} + \frac{(\alpha_d-\alpha_r)s}{4(1-\alpha_r)} - \Delta_2$$

where

$$\Delta = \frac{k\sigma(\alpha_d-\alpha_r)}{4(1-\beta)},\ \Delta_1 = \frac{k\sigma(1-\alpha_r)}{2(1-\beta)},\ \Delta_2 = \frac{k\sigma}{4(1-\beta)}$$

Appendix B

For the scenario FR-RN, taking the first-order derivatives of $p_r{}^*$, $p_d{}^*$ and w^* with respect to β, it is easily to obtain $\frac{\partial p_r{}^*}{\partial\beta} > 0$, $\frac{\partial p_d{}^*}{\partial\beta} > 0$ and $\frac{\partial w^*}{\partial\beta} > 0$.

For the scenario FR-RA, taking the first-order derivative of $\tilde{p}_r{}^*$ with respect to β, we have $\frac{\partial\tilde{p}_r{}^*}{\partial\beta} = \frac{k\sigma[(\alpha_d-\alpha_r)(4-3\alpha_r-\alpha_d)D-\theta]+3\theta(1-\theta)}{4\theta(1-\beta^2)}$.

Let $(\alpha_d-\alpha_r)(4-3\alpha_r-\alpha_d)D-\theta > 0$, then we obtain a range of θ, that is $\theta \le \theta_k$ and $\theta_k = \frac{8(1-\alpha_r-\alpha_d+\alpha_r\alpha_d)}{8(1-\alpha_r-\alpha_d+\alpha_r\alpha_d)+(\alpha_r-\alpha_d)^2+Y}$, $Y = \frac{1}{(\alpha_d-\alpha_r)(4-\alpha_d-3\alpha_r)}$. It is ease to prove $0 < \theta_k < \bar{\theta} \le 1$. Thus when $\theta \le \theta_k$, there is always $\frac{\partial\tilde{p}_r{}^*}{\partial\beta} > 0$.

Next, when $(\alpha_d-\alpha_r)(4-3\alpha_r-\alpha_d)D-\theta < 0$, there is $\theta > \theta_k$. In this situation, as long as $\eta \le \hat{\eta}$ (where $\hat{\eta} = \frac{3\theta(1-\theta)}{Z}$, $Z = (\alpha_d-\alpha_r)(4-\alpha_d-3\alpha_r)D-\theta)$, $k\sigma[(\alpha_d-\alpha_r)(4-3\alpha_r-\alpha_d)D-\theta]+3\theta(1-\theta)$ is still non-negative. Similarly, if $\eta > \hat{\eta}$, then $k\sigma[(\alpha_d-\alpha_r)(4-3\alpha_r-\alpha_d)D-\theta]+3\theta(1-\theta)$ is less than zero and we obtain $\frac{\partial\tilde{p}_r{}^*}{\partial\beta} < 0$.

Furthermore, it is straight forward to prove $\frac{\partial\tilde{p}_d{}^*}{\partial\beta} > 0$ and the first-order derivative of $\tilde{w}^*$ with respect to β is as follows: $\frac{\partial\tilde{w}^*}{\partial\beta} = \frac{(1-\alpha_r)(1-\theta)}{2(1-\beta)^2} + \frac{(2-\alpha_r-\alpha_d)}{2}\cdot\frac{\partial\tilde{p}_d{}^*}{\partial\beta} + \frac{k\sigma(1-\alpha_r)}{2(1-\beta)^2} > 0$. Thus Proposition 1 is proved.

Appendix C

For the scenario FR-RN, first we substitute the equilibrium solutions into the demand functions. We derive the demand in the retail channel:

$$Q_r = \frac{1}{4} + \frac{\alpha_d - \alpha_r}{4(1-\theta)(1-\alpha_r)}\left[\frac{(1-\theta)\theta(1-\alpha_r)(4-3\alpha_d-\alpha_r)}{D} + \left(\beta - 1\right)\frac{E+D}{D}s\right].$$

As D, E and $\frac{\alpha_d-\alpha_r}{4(1-\theta)(1-\alpha_r)} > 0$, using the first-order derivatives with respect to β, we obtain $\frac{\partial Q_r}{\partial\beta} > 0$.
The demand in the online channel is as follows:

$$Q_d = \frac{(1-\beta)s}{4(1-\theta)\theta(1-\alpha_r)D}\left[4\left(1-\theta\right)\left(1-\alpha_r\right)\left(4\alpha_d - 4\alpha_r\alpha_d - 2\theta\alpha_d - 2\theta\alpha_r + \theta\alpha_r^2 + 3\theta\alpha_r\alpha_d\right)\right].$$

As $4\alpha_d - 4\alpha_r\alpha_d - 2\theta\alpha_d - 2\theta\alpha_r + \theta\alpha_r^2 + 3\theta\alpha_r\alpha_d > 0$, using the first-order derivatives with respect to β, we obtain $\frac{\partial Q_d}{\partial\beta} < 0$.
The total demand of the dual-channel supply chain is as follows:

$$Q_t = \frac{(1-\beta)Es}{\theta D} + 1 - \frac{(1-\theta)(1-\alpha_r)(4-3\alpha_d-\alpha_r)}{\theta D}.$$

Using the first-order derivatives with respect to β, we obtain $\frac{\partial Q_t}{\partial\beta} < 0$.

For the scenario FR-RA, because $E(\tilde{Q}^*{}_r) - Q_r^* = \frac{(1-\beta)}{(1-\theta)}[\frac{(\alpha_d-\alpha_r)\Delta}{4(1-\alpha_r)A} + \Delta_2]$ is irrelevant to β. Thus we have $\frac{\partial[E(\tilde{Q}^*{}_r) - Q_r^*]}{\partial\beta} = 0$. Then the first-order derivatives of $E(\tilde{Q}^*{}_r)$ with respect to β is as follows: $\frac{\partial E(\tilde{Q}^*{}_r)}{\partial\beta} = \frac{\partial[E(\tilde{Q}^*{}_r) - Q_r^*]}{\partial\beta} + \frac{\partial Q_r^*}{\partial\beta} > 0$. Similarly, we can obtain $\frac{\partial E(\tilde{Q}^*{}_d)}{\partial\beta} < 0$ and $\frac{\partial E(\tilde{Q}^*{}_t)}{\partial\beta} < 0$. Thus Proposition 2 is proved.

Appendix D

For the scenario FR-RA, taking the first-order derivatives of $\tilde{p}_r{}^*$, $\tilde{p}_d{}^*$ and $\tilde{w}^*$ with respect to η, it is easily to obtain that $\frac{\partial\tilde{p}_r{}^*}{\partial\eta} < 0$, $\frac{\partial\tilde{p}_d{}^*}{\partial\eta} > 0$ and $\frac{\partial\tilde{w}^*}{\partial\eta} > 0$.

For the demand in the retail channel, taking the first-order derivatives of $E(\tilde{Q}^*{}_r)$ with respect to η, we have $\frac{\partial E(\tilde{Q}^*{}_r)}{\partial\eta} = \frac{\partial[E(\tilde{Q}^*{}_r) - Q_r^*]}{\partial\eta} + \frac{\partial Q_r^*}{\partial\eta}$.
Because $\frac{\partial[E(\tilde{Q}^*{}_r) - Q_r^*]}{\partial\eta} = \frac{(1-\beta)(\alpha_d-\alpha_r)}{4(1-\theta)(1-\alpha_r)A}\cdot\frac{\partial\Delta}{\partial\eta} + \frac{(1-\beta)}{(1-\theta)}\cdot\frac{\partial\Delta_2}{\partial\eta} > 0$, and $\frac{\partial Q_r^*}{\partial\eta} = 0$. Thus $\frac{\partial E(\tilde{Q}^*{}_r)}{\partial\eta} > 0$. Similarly, it is easy to prove that $\frac{\partial E(\tilde{Q}^*{}_d)}{\partial\eta} < 0$ and $\frac{\partial E(\tilde{Q}^*{}_t)}{\partial\eta} < 0$.
Thus Proposition 3 is proved.

Appendix E

By comparing the equilibrium solutions and demand functions in the scenarios FR-RN and FR-FA, we obtain the differences between each result:
The equilibrium solutions: $\tilde{p}_r{}^* - p_r{}^* = \frac{4-3\alpha_r-\alpha_d}{4(1-\alpha_r)}\cdot\frac{\Delta}{A} - \Delta_2 < 0$, $\tilde{p}_d{}^* - p_d{}^* = \frac{B+\Delta}{A} - \frac{B}{A} = \frac{\Delta}{A} > 0$

$$\tilde{w}^* - w^* = \frac{2-\alpha_r-\alpha_d}{2}\cdot\frac{\Delta}{A} + \Delta_1 > 0.$$

The demand functions: $E(\tilde{Q}^*{}_r) - Q_r^* = \frac{(1-\beta)}{(1-\theta)}[\frac{(\alpha_d-\alpha_r)\Delta}{4(1-\alpha_r)A} + \Delta_2] > 0,$

$$E(\tilde{Q}^*{}_d) - Q_d^* = -\frac{(1-\beta)}{\theta(1-\theta)}\left\{\frac{[4(1-\alpha_r) - \theta(4-3\alpha_r-\alpha_d)]\Delta}{4(1-\alpha_r)A} + \theta\Delta_2\right\} < 0 \; and \; E(\tilde{Q}^*{}_t) - Q_t^* = -\frac{k\sigma(\alpha_d-\alpha_r)(1-\alpha_r)}{D} < 0.$$

Thus Proposition 4 is proved.

Appendix F

The expected profit of the centralized supply chain is

$$E[\tilde{\pi}_{SC}] = [p_r^c(1-\alpha_r) + s\alpha_r]Q_r + [p_d^c(1-\alpha_d) + s\alpha_d]Q_d,$$

The first-order derivatives with respect to (p_r^{c*}, p_d^{c*}) are as follows:

$$\frac{\partial E[\tilde{\pi}_{SC}]}{\partial p_r^c} = \left(1-\alpha_r\right)\left(1 - \frac{(p_r^c - p_d^c)(1-\beta)}{1-\theta}\right) + \frac{((1-\alpha_d)p_d^c + \alpha_d s)(1-\beta)}{1-\theta} - \frac{((1-\alpha_r)p_r^c + \alpha_r s)(1-\beta)}{1-\theta},$$

$$\frac{\partial E[\tilde{\pi}_{SC}]}{\partial p_d^c} = \left.\frac{((1-\alpha_r)p_r^c + \alpha_r s)(1-\beta)}{1-\theta}\right) - \frac{((1-\alpha_d)p_d^c + \alpha_d s)(1-\beta)}{(1-\theta)\theta} + \frac{(1-\alpha_d)(1-\beta)(p_r^c\theta - p_d^c)}{1-\theta}.$$

So we obtain

$$p_r^{c*} = \frac{2 - s\alpha_d{}^2(1-\beta) + \alpha_d[\alpha_r(2 + s(1-\beta)(3-\theta) - 2\theta) - 2 - 2(1-\theta)\alpha_r(1 + s(1-\beta)) - \alpha_r{}^2 s(1-\beta)\theta]}{(1-\beta)((\alpha_r + \alpha_d - 2)^2\theta - 4(1-\alpha_r)(1-\alpha_d))},$$

$$p_d^{c*} = \frac{((2 - \alpha_r{}^2\theta(1 - s(1-\beta) + \theta) - \alpha_d{}^2 s(1-\beta)\theta - 3\alpha_r(1-\theta) - 2\theta)\theta - \alpha_d(2s(1-\beta)(1-\alpha_r-\theta) + \theta(1-\alpha_r-\theta+\alpha_r\theta)))}{(1-\beta)((\alpha_r + \alpha_d - 2)^2\theta - 4(1-\alpha_r)(1-\alpha_d))}.$$

The retailer's expected utility and the supplier's expected profit under the two-part tariff contract are as follows:

$$E[\tilde{\pi}_s^t] = w^t Q_r + [p_d^t(1-\alpha_d) + s\alpha_d]Q_d + F^t,$$
$$E[\tilde{\pi}_r^t] = [p_r^t(1-\alpha_r) - w^t + s\alpha_r]Q_r - F^t.$$

As the Stackelberg game leader, the supplier will set his online price equal to that in the centralized situation, i.e. $p_d^t = p_d^{c*}$. In the meanwhile, the supplier offers a wholesale price w^t to induce the retailer to set the retail price equal to that in the centralized situation, i.e. $p_r^t(w^t, p_d^{c*}) = p_r^{c*}$. Thus, by solving $p_r^t(w^t, p_d^{c*}) = p_r^{c*}$, we obtain w^t as follows:

$$w^t = \frac{w_1^t + w_2^t + w_3^t}{(1-\beta)((\alpha_r + \alpha_d - 2)^2\theta - 4(1-\alpha_r)(1-\alpha_d))},$$

where

$$w_1^t = (1-\theta)\theta(1-\alpha_r) - (2 - 3\alpha_r + \alpha_r{}^2)\theta^2 - \alpha_d{}^2(s(1-\beta)(2 - 2\alpha_r(1-\theta)) + \theta),$$
$$w_2^t = [2 + \alpha_r(\alpha_r(1 - s(1-\beta)) - 3)]\theta,$$
$$w_3^t = \alpha_d[2s(1-\beta)(1 - \alpha_r - \theta + 2\alpha_r\theta) - (1-\alpha_r)(1-\theta)(3-\alpha_r)\theta]$$

To achieve the successful coordination, each member's profit under the contract cannot be less than that in the decentralized situation. Thus, the supplier should charge a proper lump sum fee F^t from the retailer. And when F^t satisfies the following conditions, the supplier is willing to offer the contract and the retailer will also accept the contract.

$$\begin{cases} E[\tilde{\pi}_s^t] \geq E(\tilde{\pi}_s^d) \\ E[\tilde{\pi}_r^t] \geq E(\tilde{\pi}_r^d) \end{cases} \Leftrightarrow F_1^t \leq F^t \leq F_2^t,$$

where

$$F_1^t = E(\tilde{\pi}_s^d) - w^tQ_r - [p_d^t(1-\alpha_d) + s\alpha_d]Q_d,\ F_2^t = [p_r^t(1-\alpha_r) - w^t + s\alpha_r]Q_r - E(\tilde{\pi}_r^d).$$

Thus Proposition 5 is proved.

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