STORE ASSISTANCE AND COORDINATION OF SUPPLY CHAINS FACING CONSUMER’S RETURN

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Abstract. In this paper, we develop two game theoretic models of a one-manufacturer and one-retailer supply chain to study the store assistance service decision and channel coordination mechanism, where the retailer allows consumers to return mismatching product and invests on store assistance service to reduce mismatching rate. Under manufacturer Stackelberg model, we find that the players’ profits increase with mismatching rate and mismatching cost if market scale is sufficiently large. We design a quantity discount-subsidy contract to coordinate the pricing and service investment behavior of the retailer and find that the coordinated unit wholesale price increases with mismatching cost and mismatching rate if both subsidy fee and service cost are sufficiently high. By comparing with the retailer Stackelberg model, we find that (i) there exists a first-mover advantage; (ii) the unit wholesale price under retailer Stackelberg is lower than that under manufacturer Stackelberg while the retail price and service level under retailer Stackelberg is higher; and (iii) the retailer’s channel leadership raises product quantity if the probability of high mismatching loss is sufficiently low. We design a two-part margin-subsidy rate mechanism to coordinate the retailer Stackelberg supply chain.

1. Introduction. Consumer returns policy is not uncommon in practice. Consumers can return unsatisfied products to sellers for refunds or replacements. Many retailers provide a lenient returns policy, such as Wal-Mart, Nordstrom, and Gap. They allow consumers to return or exchange product without asking any question. Best Buy promises that consumers can return almost everything within 15 days for a full refund (Bestbuy.com). Many consumers have the experience of returning products because of product mismatching though those products have no defects on function. This situation often takes place when consumers are not fully informed about the properties of the product or they are unclear about whether the product fits their needs [25]. Returning product will incur a handling cost to consumer. For example, a consumer may need to revisit the store, which costs time and transportation fee. If the consumer keeps the mismatching product, the consumer faces a

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mismatching loss. When the consumer observes product mismatching loss, the consumer needs to determine whether to return the mismatching product, which affects the mismatching cost. The consumer needs to consider the (expected) mismatching cost when purchasing a product. The mismatching loss uncertainty influences market demand. Consumer returns incur handling costs to retailers, including costs of logistics, testing, and repackaging. It is estimated that the U.S. electronic industry spent $13.8 billion on handling returned products in 2007, where most of returned products are returned due to product mismatching [13]. Thus, how to reduce the mismatching rate of products is an important issue for the retailers.

The returns rate is between 11% and 20% for consumer electronics and up to 35% for high-fashion apparel [9]. Returns rate can be reduced by many ways. For example, the manufacturer can improve the design quality of products [16]. Retailers can provide appropriate service such as store assistance (SA) to decrease product mismatching rate. In this paper, we consider the latter one. Retailers can improve SA service through providing more shelf spaces to display sample models of the product, hiring skilled salespersons or training salespersons and enhancing trial experience [33]. For example, Sierra Trading Post Inc., a seller of outdoor and recreational foot-wear products, invests on SA to reduce product returns occurring due to wrong size and colors, through hiring a size and fit specialist for shoes and presenting appropriate colors and shapes [26]. Though SA can reduce returns rate, it incurs a cost to the retailer. The retailer makes a trade-off between returns handling cost reduction and SA cost. In this paper, we will investigate how to make a SA level decision to reduce returns rate.

Much of the literature about supply chain management studies the situation where the manufacturer acts as a pricing leader and the retailer acts as a pricing follower, i.e., manufacturer Stackelberg (MS) supply chain. However, some giant retailers are emerging recently, say, Wal-Mart, Best buy, Home Depot, and Amazon [36]. In this case, the retailer may have the ability to move first before the manufacturer makes the decisions, i.e., retailer Stackelberg (RS) supply chain. For example, in supply chains with intermediation (e.g., Li & Fung, Global Sources, The Connor Group), the retailer usually acts as the leader. Suning, one of the largest consumer electronics retailers in China, acts as a leader and designs an option mechanism to coordinate the production quantity of the suppliers [29]. We investigate both MS and RS supply chains, and compare them to examine the effect of channel leadership on equilibrium outcome.

It is well known that the decentralization of supply chain raises the retail price due to double marginalization effect, which harms the benefit of the supply chain. Some coordination mechanisms are developed to avoid this negative effect [1], say, quantity discount, revenue-sharing, and buyback contracts. Traditional all-unit quantity discount mechanism cannot coordinate the supply chain in which the retailer carries out service investment. We combine all-unit quantity discount contract and SA subsidy to coordinate the MS supply chain. Although many mechanisms are developed to coordinate a MS supply chain, coordination issue in the RS supply chain is rarely discussed. We will investigate how to coordinate the RS supply chain via a two-part margin-subsidy rate contract.

To be specific, we develop game theoretic models of a one-manufacturer and one-retailer supply chain to study the SA service of reducing mismatching rate and channel coordination. Here consumers decide whether to return the mismatching product by comparing the realized mismatching loss and the returns handling cost.
The retailer provides a returns policy to consumers to replace the mismatching product with a new variant of the product. We develop two types of models, MS model and RS model. Under MS model, we study the equilibrium decisions of the players and design a quantity discount-subsidy mechanism to coordinate the pricing and SA investment behavior of the retailer. We find that the profits of both players increase with mismatching cost and mismatching rate if the market scale is sufficiently large and the coordinated unit wholesale price increases with them under some conditions. Under RS model, we design a two-part margin-subsidy rate mechanism to coordinate the wholesale pricing behavior of the manufacturer. By comparing the two models, we examine the effect of channel leadership on the equilibrium outcome and find that the unit wholesale price under RS is lower than that under MS; and the retailer’s profit under RS is higher than that under MS.

2. Literature review. This paper is closely related to consumer returns, SA service, supply chain coordination, and channel leadership structure.

2.1. Consumer returns. Some of the consumer returns models consider deterministic demand. For example, Mukhopadhyay and Setoputro [17] assume that both the demand and the returns quantity are linear functions of the refund amount. A lot of existing works about consumer returns assume that market demand is stochastic [16, 21]. Ruiz-Benitez and Muriel [21] assume that the returns quantity from consumers is a proportion of sales quantity (also see [16]) and ignore the consumer’s returns handling cost. However, we consider the returns handling cost and the mismatching loss of consumers. Some works are made in studying consumer returns based on the consumer’s behavior. For example, Xiao et al. [35] explicitly model the effect of consumer’s returns handling cost on the probability that the consumer returns the product. Ofek et al. [18] assume that all mismatching consumers will return the products. Shi and Xiao [22] study whether the manufacturer allows consumers to return the mismatching product in a vendor-managed inventory supply chain. Yoo [37] investigates the relationship between returns policy and product quality decisions, where the returns quantity is a proportion of market size. In our model, there are two types of consumers following mismatching loss; the consumer’s utility is influenced by both mismatching rate and the (conditional) expected mismatching loss; and only the consumers with high mismatching loss return the mismatching products.

2.2. Store assistance service. Product returns incur handling costs to both the retailer and consumers. Some scholars suggest that the retailer can provide SA service to reduce returns (replacements) rate [7, 8, 24]. For example, Wernerfelt [31] claims that SA can greatly help consumers find the products matching with their needs. Xiao and Shi [33] study information revelation mechanism of a supply chain, where the retailer provides SA to reduce consumer returns rate and increase demand. Similarly, we also consider the SA service of the retailer. However, in this paper, we focus on coordination problem and the effect of channel structure on equilibrium outcome.

2.3. Supply chain coordination. To avoid double marginalization effect, various contracts are designed to coordinate the supply chain, for instance, buyback/markdown contract [2, 35], target rebate contract [7], quantity discount contract [20], two-part tariffs [12, 20], and subsidy contract [32]. Ferguson et al. [7] find that common mechanisms cannot coordinate the supply chain when the effort
of the retailer influences the returns rate and they propose a target rebate mechanism. Xiao et al. [35] develop buyback and markdown mechanisms to coordinate the supply chain with partial refund amount.

This paper is related to quantity discount mechanism [3, 33]. Weng [30] studies the all-unit quantity discount contract and incremental quantity discount. Xiao et al. [34] study the coordination of a supply chain competing with an integrated outside firm on price and leadtime under the leadtime-decision-first scenario and the wholesale-price-decision-first scenario. Huang et al. [10] study the coordination of a supply chain facing consumer returns, where the consumer returns quantity is a function of retailer’s effort. Liu et al. [14] develop a Newsvendor model with stochastic demand to investigate how to coordinate the order quantity and refund amount behavior of the retailer. Unlike Huang et al. [10] and Liu et al. [14], we derive the market demand from the consumer’s utility and investigate the effects of the consumer’s characteristics (including mismatching loss, returns handling cost, mismatching rate) and the retailer’s SA decision on the coordination mechanism. We study supply chain coordination under MS model and RS model. Under MS model, we design a quantity discount-subsidy contract to induce a higher quantity and SA level; under RS model, we suggest a two-part margin-subsidy rate contract for the retailer to induce a lower wholesale price.

2.4. Channel leadership structure. Many existing models assume that the manufacturer acts as the leader in a supply chain [21]. There are a lot of “power manufacturers” in the market such as Apple, Caterpillar, and luxury goods producers [36]. However, more and more large retailers appear recently. Some retailers act as the leader in their supply chains, i.e., RS supply chain [15]. Dukes et al. [5] study a supply chain consisting of one manufacturer and two competing retailers, where one of the retailers acts as the leader and decides the assortment first. Choi [4] studies three different game models: MS game, Nash game, and RS game between two competing manufacturers and a common retailer. Shi et al. [23] study the impacts of market power and demand model on supply chain members’ performances. Xue et al. [36] examine how channel leadership structure influences the performances of players and the surplus of consumers, and find that the production quantity is the highest and the retail price is the lowest under MS while the channel profit is the highest under RS. However, we find that the effect of channel leadership on the quantity depends on the probability of high mismatching loss. Ertek and Griffin [6] study the impacts of power structure on price and profits in a supply chain. Unlike Ertek and Griffin [6], we find that a first-mover advantage exists.

This paper contributes to the literature by considering the pricing and SA decisions and channel coordination of a supply chain in which the retailer allows consumers to replace mismatching product. Here the retailer provides SA service to reduce mismatching rate, so returns rate. A returns handling cost or mismatching loss is incurred to the consumer who buys a mismatching product. We consider MS and RS models, and examine the effect of channel leadership on equilibrium outcome. Under each model, we design a mechanism to coordinate the supply chain.

3. The basic model. Consider a supply chain consisting of one manufacturer and one retailer. The manufacturer produces products with a unit cost $c$, and sells them to consumers through the retailer. The unit wholesale price is $w$ and the retail price is $p$. In order to encourage consumers to buy, the retailer provides returns policy, which is a common practice in retailing industries [27]. Usually, returns policy
includes two different forms. One allows consumer to return a product for a refund. The other allows consumer to replace it with a new variant of the product freely. In this paper, we consider the latter that is caused by product mismatching. We assume that, after replacing for one time, the consumer can get the right product. A unit returns handling cost $h_R$ for returned product is incurred to the retailer. In order to reduce returns rate, the retailer invests on SA to help consumers find right products.

The retailer decides the SA level $s$, $0 \leq s \leq 1$. A service cost $\eta s^2/2$ is incurred to the retailer, where $\eta$ is service cost factor. This cost structure is commonly used in the economics literature, which describes the phenomenon that the marginal cost is increasing [8, 18, 28]. The mismatching rate is $r$ when the retailer does not provide SA service, $0 < r < 1$. Following Xiao and Shi [33], the mismatching rate will decrease to $(1 - s)r$ if the retailer offers SA level $s$. The unit returns handling cost for consumers is $h_C$. Each consumer at most buys one unit product.

The mismatching consumer loses a value $b$ if the consumer does not replace the mismatching product. The loss $b$ takes $b_H$ with probability $\alpha$, and $b_L$ with probability $1 - \alpha$, $0 < b_L < b_H$ and $0 < \alpha < 1$ [22]. That is, there are two consumer segments following the mismatching loss. We refer to $\alpha$ as the probability of high loss. A mismatching consumer knows his loss only when he observes the product mismatching. All consumers return the mismatching products if $h_C < b_L$ and all consumers do not return them if $h_C > b_H$. To model the effect of the mismatching loss on the returns rate (replacement rate), we consider the case of $b_L < h_C < b_H$. Here the type-$H$ consumers return the mismatching products while the type-$L$ consumers keep them. Thus, when the product mismatching happens, the (conditional) expected mismatching loss is

$$\bar{b}_1 = \alpha \cdot \min\{b_H, h_C\} + (1 - \alpha) \cdot \min\{b_L, h_C\} = \alpha h_C + (1 - \alpha) b_L.$$ 

The consumer’s valuation over a unit product is $v$. Similar to Shi and Xiao [22], we assume that for each consumer segment, $v$ is uniformly distributed over the interval $[0, \bar{v}]$. We normalize the total scale of consumers in two segments per unit line to one. Thus, the total scale of potential consumers is $\bar{v}$, referring to as market scale.

According to the above discussion, the (expected) utility of consumer is $U(p, s) = v - p - (1 - s)r\bar{b}_1$. A consumer buys a product only when the consumer can achieve a non-negative utility, i.e., $U(p, s) \geq 0$. Thus, only consumers satisfying the condition $v \geq p + (1 - s)r\bar{b}_1$ will buy. Further, we obtain market demand

$$q = \bar{v} - p - (1 - s)r\bar{b}_1$$  

Equation (1) indicates that the higher the SA level is, the higher the market demand will be. Because we only consider replacement here, the actual sales quantity equals the market demand given by (1) [18].

The profit function of the manufacturer is

$$\pi_M = (w - c)[\bar{v} - p - (1 - s)r\bar{b}_1]$$  

Note that the actual returns rate is $(1 - s)r \cdot \alpha$ because only the high-loss consumers return the mismatching product. The expected profit function of the retailer is

$$\pi_R = [p - w - (1 - s)r \cdot \alpha \cdot h_R][\bar{v} - p - (1 - s)r\bar{b}_1] - \eta s^2/2.$$  

The first term of (3) denotes the expected profit of selling quantity $q$. The higher the probability of the high-loss consumers $\alpha$, the lower the expected unit profit and
the demand of the retailer will be. From (3), we see that the retailer will offer a retail price \( p > w + (1 - s)r h_R \). To ensure the practice meaning, we assume that when the retailer provides no SA service and offers a retail price equal to the expected unit cost of the channel \( c + r h_R \), the retailer can get a positive demand, i.e., \( \tilde{v} > c + rh \), where \( h = \alpha h_R + \beta_1 \). \( h \) is the sum of the expected returns handling cost of the retailer and the expected loss of consumer from mismatching when the product mismatching happens. We refer to \( h \) as the sum of mismatching cost.

We first consider the MS model in which the manufacturer is the leader and the retailer is the follower. Specifically, the time sequence of the game is as follows:

(i) The manufacturer decides the unit wholesale price \( w \)
(ii) Observing the unit wholesale price, the retailer decides the retail price \( p \) and the SA level \( s \).

In the following, we obtain the subgame perfect Nash equilibrium (SPNE) by employing backward induction technique.

4. Equilibrium analysis.

4.1. **Equilibrium outcome of the decentralized supply chain.** Proposition 1 summarizes the equilibrium decision of the decentralized supply chain.

**Proposition 1.** Assume \( \eta > \hat{\eta}_1 = \max\{r^2 h^2 / 2, rh(\bar{v} - c + rh) / 4\} \). The SPNE decisions are as follows: the unit wholesale price of the manufacturer is \( w^* = (c + \bar{v} - rh) / 2 \). The retail price is \( p^* = \frac{r h (\bar{v} - c + rh)}{2(2 \eta - r^2 h^2)} \). The SA level is \( s^* = \frac{r h (\bar{v} - c + rh)}{2(2 \eta - r^2 h^2)} \). At SPNE, the demand is \( q^* = \frac{\eta (\bar{v} - c + rh)}{2(2 \eta - r^2 h^2)} \). The profits of the retailer and the manufacturer are \( \pi^*_R = \frac{\eta (\bar{v} - c + rh)^2}{8(2 \eta - r^2 h^2)} \) and \( \pi^*_M = \frac{\eta (\bar{v} - c + rh)^2}{4(2 \eta - r^2 h^2)} \).

In Proposition 1, the assumption of \( \eta > \hat{\eta}_1 \) ensures that the SPNE decisions exist and the SPNE SA level is an interior solution, i.e., \( s^* \in (0, 1) \). This assumption is commonly used in the economics literature, which implies that the retailer’s SA cost is not too inexpensive [33]. When the SA level is one, all consumers buy the right products and do not return them. To avoid trivial cases, we consider the case with interior solution for SA level.

Proposition 1 implies that when the mismatching rate \( r \) or the sum of mismatching cost \( h \) increases, the manufacturer will decrease the unit wholesale price to bear a part of the mismatching cost, which prevents the decrease of quantity.

From Proposition 1, we can derive the following.

**Proposition 2.** (i) When the mismatching rate \( r \) or the sum of mismatching cost \( h \) increases, the SA level \( s^* \) increases if and only if \( \bar{v}_1 = c + 4 rh \eta / (2 \eta + r^2 h^2) \); the quantity \( q^* \) increases if and only if \( \bar{v}_2 = c + (r^2 h^2 + 2 \eta) / (2 rh) \); and the profits of the players increase if and only if \( \bar{v}_3 = c + 2 \eta / (r h) \).

(ii) When the SA cost \( \eta \) increases, the SA service level, demand and profits of both players will decrease; the retail price increases with the SA cost if and only if \( \alpha h_R > \beta_1 \).

From Proposition 2, we see that when the market scale is sufficiently large, the profits of both players increase with the sum of mismatching cost. This result may be counterintuitive. We can explain it as follows: if the market scale is very high, the retailer will enhance service level to reduce the returns rate as the sum of mismatching cost increases, which results in a higher demand. Moreover, the
manufacturer decreases the unit wholesale price to share the cost, which reduces the double marginalization effect. The increase of the retailer’s benefit is larger than the total loss incurred by both the increase of SA cost and the direct negative effect of the sum of mismatching cost. As a consequence, the retailer’s profit increases. A higher demand enhances the manufacturer’s profit. There is a similar explanation for the mismatching rate.

The effect of the SA cost on the retail price depends on whether the expected returns handling cost of the retailer is higher than the expected mismatching loss of consumer for a mismatching product. Specifically, when the expected returns handling cost of the retailer is higher than the expected mismatching loss of consumer, the retailer increases the retail price to compensate the increase of SA cost; otherwise, the retailer decreases the retail price to offset the negative effect of lower SA level on demand. When the SA cost (η) increases, the retailer decreases the SA level to save investment, which decreases the market demand as well as the players’ profits.

4.2. Coordination of supply chain via a quantity discount-subsidy contract. In this subsection, we investigate how to coordinate the supply chain. As a benchmark for coordination, we consider the centralized supply chain. The channel profit is

\[ \pi_C = [p - c - (1 - s)r \cdot \alpha \cdot h_R][\bar{v} - p - (1 - s)r\bar{b}_1] - \eta s^2/2. \]

Similar to Proposition 1, we can derive the following.

**Lemma 1.** When \( \eta > \hat{\eta}_2 = \max\{r^2h^2/2, rh(\bar{v} - c)/2\} \), the optimal SA level and retail price of the centralized supply chain are

\[ s^*_C = \frac{rh(\bar{v}-c-rh)}{2r^2h^2-\bar{v}h^2}, p^*_C = \frac{\bar{v}c+\bar{v}h^2-\bar{v}^2r^2h^2}{2r^2h^2}. \]

Under the optimal decisions, the demand is

\[ q^*_C = \frac{\eta(\bar{v} - c - rh)}{(2\eta - r^2h^2)} \]

and the channel profit is

\[ \pi^*_C = \eta(\bar{v} - c - rh)/2(2\eta - r^2h^2). \]

Comparing with the decentralized setting, we find that the efficiency of the decentralized system is 75%, i.e., the channel profit under the decentralized setting is 75% of that under the centralized setting. The SA level and the demand under the decentralized setting are lower than those under the centralized system. Thus, it is necessary to design a mechanism to raise the SA level and the retailer’s quantity.

According to Xiao et al. [32], we consider an all-unit quantity discount contract with SA subsidy \((w(q), f(s))\), where \(w(q) = \begin{cases} w_1, & q \geq s_0, \\ w_2, & q < s_0, \end{cases}\) and \(f(s) = \begin{cases} F, & s \geq s_0, \\ 0, & s < s_0. \end{cases}\) We call it as quantity discount-subsidy contract. Let the proportion of the retailer’s profit in the channel profit be \(0 < \gamma < 1\). Proposition 3 summarizes the coordination mechanism.

**Proposition 3.** The supply chain can be coordinated by quantity discount-subsidy contract \((w(q), f(s))\) with \(w(q) = \begin{cases} w_1^*, & q \geq q^*_C, \\ w_2, & q < q^*_C, \end{cases}\) and \(f(s) = \begin{cases} F, & s \geq s^*_C, \\ 0, & s < s^*_C, \end{cases}\) where

\[ w_1^* = \frac{(2\eta - r^2h^2)F}{\eta(\bar{v} - c - rh)} + \frac{c(1 + \gamma) + (\bar{v} - rh)(1 - \gamma)}{2} = F/q^*_C + c + (\bar{v} - c - rh)(1 - \gamma)/2, \]

and \(w_2\) is sufficiently high so that the retailer has no incentive to take it.
Proposition 3 implies that the coordinated unit wholesale price $w_1^*$ increases with the SA cost. Intuitively, when the SA cost increases, the SA level of the centralized system decreases, which further decreases the market demand of the centralized system. As a result, the subsidy fee per unit demand increases. Thus, the manufacturer will charge a higher unit wholesale price to compensate the subsidy fee. The Pareto condition of supply chain coordination is \( \frac{\pi_R}{\pi_C} \leq \gamma \leq 1 - \frac{\pi_M}{\pi_C} \).

From Proposition 3, we derive the following.

**Corollary 1.** (i) The coordinated unit wholesale price $w_1^*$ increases with the sum of mismatching cost $h$ and the mismatching rate $r$ if the fixed subsidy fee and the SA cost are sufficiently high ($F > (1 - \gamma)(\bar{v} - c - hr)^2/4$ and $\eta > \bar{\eta}_3 = 2Fhr(2\bar{v} - 2c - hr)/[4F - (1 - \gamma)(\bar{v} - c - hr)^2]$); (ii) the coordinated unit wholesale price decreases with the market scale if the fixed subsidy fee is sufficiently high ($F > \eta(1 - \gamma)(\bar{v} - c - hr)^2/[2(2\eta - r^2h^2)]$).

Corollary 1(i) is counterintuitive because one expects that the manufacturer decreases the unit wholesale price to share the cost incurred by product mismatching. When the sum of mismatching cost or the mismatching rate increases, the retailer’s cost incurred by the mismatching increases such that the manufacturer decreases the unit wholesale price to share the cost with the retailer (negative effect). On the other hand, if the SA cost is sufficiently high, it decreases the optimal quantity such that the service subsidy fee per unit demand increases (positive effect). When the service subsidy fee is sufficiently high, the positive effect on the unit wholesale price outweighs the negative effect. As a result, the manufacturer raises the unit wholesale price. We have a similar explanation for Corollary 1(ii).

5. **The retailer Stackelberg model.** In the basic model, we assume that the manufacturer is the leader. However, with the emergence of retailer giants such as Hudson’s Bay, Gome, Superstore, more and more retailers act as pricing leaders. Some works have been made in studying retailer Stackelberg (RS) supply chain [5, 19, 29]. In this section, we develop a RS model. By comparing it with the MS model, we examine the impact of channel leadership on the equilibrium outcome. Under RS, the retailer charges a marginal profit $m$ [4, 11]. Specifically, the time sequence of the game is as follows:

(i) The retailer decides profit margin $m$

(ii) The manufacturer decides the unit wholesale price $w$

(iii) Observing the unit wholesale price, the retailer determines the SA level $s$ and market demand realizes.

Here the retailer determines the SA level until the manufacturer sets the unit wholesale price and the unit wholesale price affects the retailer’s quantity, which can avoid “holdup” problem.

According to the above, the retail price is $(m + w)$. We use subscript “A” to denote this alternative model. Similar to (1), we obtain the demand

$$q_A = \bar{v} - (w + m) - (1 - s)r\bar{b}_1.$$

The profit of the retailer is

$$\pi_{RA} = [m - (1 - s)\rho h_R][\bar{v} - (w + m) - (1 - s)r\bar{b}_1] - \eta s^2/2.$$

Similar to (2), we can derive the manufacturer’s profit

$$\pi_{MA} = (w - c)[\bar{v} - (w + m) - (1 - s)r\bar{b}_1].$$
5.1. **Equilibrium outcome and channel leadership.** Proposition 4 summarizes the SPNE decisions of the decentralized supply chain.

**Proposition 4.** Assume $\eta > 2r^2\alpha h_R$ and $f_1(\eta) > 0$. The SPNE profit margin and SA level of the retailer are

$$m^*_A = \frac{\{2(B + r\alpha h_R)\eta^2 - \eta^2\alpha h_R[6b_1B + \alpha h_R(6r\bar{b}_1 + B)]\eta^2 + r^4\alpha^2\bar{b}_1^2h_R^2[5\bar{b}_1B + \alpha h_R(3r\bar{b}_1 + 2B)]\eta - hr^6\alpha^5\bar{b}^2_1h_R^2(v - c)\}/f_1(\eta)}{2(\eta - 2r^2\alpha b_1 h_R)(\eta - r^2\alpha b_1 h_R)}.$$  

Thus, the manufacturer decreases the unit wholesale price to induce a higher quantity. In addition, Fig. 1 implies that a higher probability of high loss decreases the unit wholesale price. Intuitively, when the probability of high loss increases, the consumer’s returns rate increases such that the retailer’s expected returns handle cost for a unit product increases. Thus, the manufacturer decreases the unit wholesale price to share the cost and stimulate demand.

**Figure 1.** The unit wholesale price versus the probability of high loss

From Fig. 1, we see that the unit wholesale price under RS is lower than that under MS, i.e., the leadership of the retailer decreases the unit wholesale price. This result is counterintuitive because one expects that “holdup” phenomenon emerges under RS. However, under RS, the retailer charges a higher profit margin than under MS, which decreases the market demand through increasing the retail price. Thus, the manufacturer decreases the unit wholesale price to induce a higher quantity. In addition, Fig. 1 implies that a higher probability of high loss decreases the unit wholesale price. Intuitively, when the probability of high loss increases, the consumer’s returns rate increases such that the retailer’s expected returns handling cost for a unit product increases. Thus, the manufacturer decreases the unit wholesale price to share the cost and stimulate demand.
Figure 2. The retail price versus the probability of high loss

Figure 3. The SA level versus the probability of high loss

Figure 4. The quantity versus the probability of high loss
From Figs. 2 and 3, we know that the retail price and SA level under RS are higher than those under MS. We can explain it as follows: on one hand, the channel leadership of the retailer decreases the unit wholesale price (see Fig. 1), which has a negative effect on the retail price. On the other hand, under RS, the retailer can obtain a higher profit margin, which has a positive effect on the retail price. Moreover, the retailer will raise SA level to increase the market demand, which has a positive indirect effect on the unit wholesale price, so the retail price. As a result, the retailer’s channel leadership enhances the retail price and the SA level because its positive effect on the retail price is larger. In addition, Fig. 3 implies that when the probability of high loss increases, the retailer raises the SA level to reduce its return handling cost and increase the market demand. Moreover, the retail price decreases with the probability of high loss (see Fig. 2).

Fig. 4 implies that the effect channel leadership on the quantity depends on the probability of high loss. Specifically, the quantity under RS is higher than that under MS if and only if the probability of high loss is sufficiently low. The effects of
channel leadership on the retail price and the SA level accounts for this phenomenon (see Figs. 2 and 3).

From Fig. 5, we see that the retailer’s profit under RS is higher than that under MS because of a higher profit margin for the retailer (see Figs. 1 and 2), which implies that there exists a first-mover advantage for the retailer. There is a similar result for the manufacturer, omitting its figure.

Fig. 6 implies that the quantity increases with the mismatching loss of low type. This is a counterintuitive result because one expects that a higher mismatching loss decreases market demand. However, when the mismatching loss of low type increases, the consumer’s expected disutility from mismatching increases, which has a negative effect on market demand. To stimulate demand and reduce returns handling cost, the retailer raises the SA level to reduce mismatching rate. Moreover, the retail price is decreased to further increase market demand. As a result, a higher mismatching loss of low type increases the quantity because its positive effect on demand is higher than the negative effect.

5.2. Coordination of supply chain via a two-part margin-subsidy rate contract. Under RS, the supply chain coordinator is the retailer rather than the manufacturer. Thus, the quantity discount mechanism cannot be used to coordinate the RS supply chain. We consider a two-part margin-subsidy rate (TMSR) scheme \((m(w), t), 0 \leq t \leq 1\). Specifically, the retailer offers a two-part margin contract \(m(w) = \left\{ \begin{array}{ll} m, & \text{if } w \leq \hat{w} \\ \bar{m}, & \text{if } w > \hat{w} \end{array} \right\}

and charges the manufacturer a subsidy rate \(t\) for the SA investment, where \(m < \bar{m}\). The two-part margin scheme can induce a lower unit wholesale price, which reduces the double marginalization effect.

Under TMSR scheme, the retailer’s profit is

\[
\pi_{RA} = [m - (1 - s)\alpha h_R][\bar{v} - (w + m) - (1 - s)\bar{b}_1] - (1 - t)\eta s^2/2, \tag{7}
\]

the manufacturer’s profit is

\[
\pi_{MA} = (w - c)[\bar{v} - (w + m) - (1 - s)\bar{b}_1] - t\eta s^2/2, \tag{8}
\]

Proposition 5 summarizes the coordination mechanism of supply chain under RS.

**Proposition 5.** (i) The RS supply chain can be coordinated if the retailer commits SA level \(s^*_C\) and charges margin \(m_A(w) = \left\{ \begin{array}{ll} m_A(t), & \text{if } w \leq p^*_C - m_A(t) \\ \bar{m}_A, & \text{if } w > p^*_C - m_A(t) \end{array} \right\}, \)

where \(0 < t < \bar{b}_1/h\), \(m_A(t) = s^*_C(1 - t)\eta/(r\bar{b}_1) - \alpha h_R[\bar{v} - p^*_C - 2rb_1(1 - s^*_C)]/\bar{b}_1\), and \(\bar{m}_A\) is sufficiently large such that the manufacturer does not take it; (ii) the SA service commitment is credible.

In Proposition 5, since the retailer is the contract designer, the retailer needs to commit a SA level. To maximize the channel profit as well as the retailer’s profit, the retailer will commit the optimal SA level of the centralized system. Since the retailer carries out SA investment after observing the unit wholesale price, the retailer may deviate from the SA service commitment, where a credibility issue of service commitment emerges. Proposition 5(ii) suggests that the service commitment is credible.

Proposition 5(i) implies that a lower SA subsidy rate is along with a higher coordinated profit margin for the retailer. Intuitively, when the service subsidy rate decreases, the retailer will charge a higher profit margin to compensate the SA cost.
In addition, we find that the upper-bound of the subsidy rate ($\bar{b}_1/h$) increases with the consumer’s unit returns handling cost and the mismatching loss of the low-loss consumers while decreases with the retailer’s unit returns handling cost and the probability of the high-loss consumers.

6. Conclusions. For some products, a consumer observes whether the product fits and realizes the mismatching loss only after the consumer has used the product. In order to encourage consumers to buy, retailers provide returns policy. Consumer return is often caused by product mismatching. In order to reduce the mismatching rate, the retailer invests on SA service, which incurs a service cost. We develop two Stackelberg game models of a one-manufacturer and one-retailer supply chain to study SA decision and channel coordination, and examine the effect of channel leadership on equilibrium outcome.

Under MS, the manufacturer is a pricing leader and the retailer determines the retail price and SA level decisions to react to the manufacturer’s unit wholesale price. We find that: (i) when mismatching rate or the sum of mismatching cost (including the expected returns handling cost of the retailer and the expected mismatching loss of consumer) increases, the manufacturer will decrease the unit wholesale price to share the returns handling cost with the retailer; (ii) the market scale can reverse the effects of the mismatching rate and the sum of mismatching cost on equilibrium decisions and profits. After that, we suggest a quantity discount-subsidy contract to coordinate the supply chain.

Under RS, the retailer acts as a pricing leader and charges the manufacturer a profit margin. We find that when the probability of the high-loss consumer increases, the unit wholesale price and the retail price decrease, while the retailer invests a higher SA level to reduce mismatching rate, which has a positive indirect effect on market demand. The probability of high-loss has a direct negative effect on demand. As a result, the product quantity first decreases and then increases with the probability of high-loss. By comparing it with MS model, we find that (i) the unit wholesale price under RS is lower than under MS, but the retail price, SA level and the profit of the retailer under RS are higher. The players can be better off when they become the pricing leader of the supply chain, i.e., there exist a first-mover advantage. In addition, a TMSR contract is designed to coordinate the RS supply chain.

In this paper, we consider free replacement for mismatching product. In reality, some firms charge consumers a restocking fee for returned product. Thus, the endogenous restocking fee setting is an interesting extension. We assume that there is only one retailer. The price and service competition between the retailers affects the equilibrium outcome. Coordination of the supply chain with competing retailers who invests on SA service to reduce mismatching rate may be an outlet.

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Appendix A.

Proof of Proposition 1. The Hessian matrix of the retailer’s profit over $(p, s)$ is

$$
\begin{pmatrix}
-2 & -r_\alpha h_R + r\bar{b}_1 \\
-r_\alpha h_R + r\bar{b}_1 & -\eta + 2\bar{b}_1 h_R r^2 \alpha
\end{pmatrix},
$$
which is negatively definite if \( \eta > r^2h^2/2 \). Solving the first-order conditions \( \partial \pi_R / \partial p = 0 \) and \( \partial \pi_R / \partial s = 0 \) for \((p, s)\), we have

\[
p(w) = \frac{(\bar{v} + w)\eta + r\alpha h_R - r^2\bar{v}\alpha h^2_R - \tilde{b}_1 r^2 R \tilde{v}(\bar{v} + w)\alpha + \eta - r^2 w\tilde{b}_1^2}{2\eta - r^2 h^2}
\]

\[
s(w) = \frac{r(\bar{v} - w - rh)}{2\eta - r^2 h^2}
\]

Inserting \( p(w) \) and \( s(w) \) into (2), we obtain \( \pi_M(w) = \eta(w - c)(\bar{v} - w - rh)/(2\eta - r^2 h^2) \), which is a concave function of \( w \) following from \( \eta > r^2h^2/2 \). Solving the first-order condition \( d\pi_M(w)/dw = 0 \), we have

\[w^* = (c + \bar{v} - rh)/2.\]

Further, we can get the optimal retail price, SA service level, demand and profits of both players.

From \( \bar{v} > c + rh \) and \( \eta > r^2h^2/2 \), we have \( w^* > 0 \). Note that \( w^* \) is a decreasing function of \( \eta \). Furthermore, \( w^* < 1 \) is equivalent to \( \eta > rh(\bar{v} - c + rh)/4 \). \(\)

**Proof of Proposition 2.** Part (i) Differentiating \( s^* \) with respect to \( r \), we have \( \partial s^*/\partial r = h((\bar{v} - c)(2\eta + r^2 h^2) - 4hr\eta)/\left(2(2\eta + r^2 h^2)^2\right) \). If \( \bar{v} > \bar{v}_1 = c + \frac{rh}{2\eta + r^2 h^2} \), we have \( \partial s^*/\partial r > 0 \). Note that \( \bar{v} > \bar{v}_1 \) is nonempty if \( \eta = \bar{\eta}_1 \). Differentiating \( q^* \) with respect to \( r \), we have \( \partial q^*/\partial r = -\frac{\eta (\bar{v} - c)(2\eta + r^2 h^2) - 4hr\eta}{\left(2(2\eta + r^2 h^2)^2\right)} \). We can show that \( \partial q^*/\partial r > 0 \) if and only if \( \bar{v} > \hat{v}_2 = c + (r^2 h^2 + 2\eta)/(2rh) \). Here \( \bar{v} > \hat{v}_2 \) is nonempty if \( \eta = \bar{\eta}_1 \). From \( \bar{v} > c + rh \), it follows that \( \pi_M^* \) and \( \pi_R^* \) are increasing functions of \( r \) if and only if \( \bar{v} > \hat{v}_3 = c + 2\eta/(rh) \). Here \( \bar{v} > \hat{v}_3 \) is nonempty if \( \eta = \bar{\eta}_1 \). Similarly, we can show the effect of \( h \).

Part (ii) Note that \( \bar{v} > c + rh \) and \( h = \alpha h_R + \hat{b}_1 \). Differentiating \( p^* \) with respect to \( \eta \), we have \( \partial p^*/\partial \eta = \frac{r^2 h(\bar{v} - c - rh)(\alpha h_R - \hat{b}_1)}{2(2\eta - r^2 h^2)^2} \), which is positive if and only if \( \alpha h_R > \hat{b}_1 \).

**Proof of Lemma 1.** The Hessian matrix of \( \pi_C \) over \((p, s)\) is

\[
\begin{pmatrix}
-2 & -r\alpha h_R + \hat{b}_1 \\
-r\alpha h_R + \hat{b}_1 & -\eta + 2hrR^2 \alpha \hat{b}_1
\end{pmatrix},
\]

which is negatively definite if \( \eta > r^2h^2/2 \). Solving the first-order conditions \( \partial \pi_C / \partial p = 0 \) and \( \partial \pi_C / \partial s = 0 \) for \((p, s)\), we can obtain \( p_C^* \) and \( s_C^* \), given by Lemma 1. From \( \bar{v} > c + rh \) and \( \eta > r^2h^2/2 \), we see \( s^* > 0 \). \( s^* < 1 \) is equivalent to \( \eta > rh(\bar{v} - c)/2 \). \(\)

**Proof of Proposition 3.** To coordinate the supply chain, the thresholds of quantity and SA should be those of the centralized system, i.e., \( q_0 = q_C^* \) and \( s_0 = s_C^* \).

We first consider the case where the retailer wants to get \( w_1 (> c) \) and SA subsidy \( F \). From Proposition 1, it follows that if \( s = s(w_1) \), then we have

\[
q(p(w_1), s(w_1), w_1) = \eta(\bar{v} - w_1 - rh)/2(2\eta - r^2 h^2) \text{ and } \pi_R(p(w_1), s(w_1), w_1) = \eta(\bar{v} - w_1 - rh)/2(2\eta - r^2 h^2).
\]

From \( \eta > r^2h^2/2 \), we see that the retailer’s quantity \( q(p(w_1), s(w_1), w_1) \) and the retailer’s profit \( \pi_R(p(w_1), s(w_1), w_1) + F \) decreases with the unit wholesale price \( w_1 \). Since \( w_1 > c \), we have \( q(p(w_1), s(w_1), w_1) < q(p(c), s(c), c) = q_C^* \). If \( s = s_C^* \), we can also show that the retailer’s quantity is lower than \( q_C^* \). Thus, when the retailer wants to get \( w_1 \), the optimal quantity of the retailer is \( q_C^* \). Similarly, when the retailer wants to take SA subsidy \( F \), the optimal SA service level is \( s_C^* \). Further, from (1), we can get the optimal retail price \( p_C^* \). That is, the retail price and SA
level decisions are equal to those of the centralized supply chain. According to Lemma 1, inserting $p_C^*$ and $s_C^*$ into (3), we have

$$\pi_R(p_C^*, s_C^*, w_1) = \eta(\bar{v} - c - rh)(c + \bar{v} - rh - 2w_1)/(2(2\eta - r^2h^2))$$

Solving $\pi_R(p_C^*, s_C^*, w_1) + F = \gamma^\ast \pi_C^\ast$ for $w_1$, we obtain $w_1^\ast$.

When the retailer wants to offer SA service level $s(< s_C^\ast)$ and gets the unit wholesale price $w_1^\ast$, the retailer will order the quantity $q_C^*$ from the manufacturer. From (1), we see that $s(p) = 1 - (\bar{v} - p - q_C^*)/(rh_1)$. Thus, the retailer chooses $p$ to maximize $\pi_R(p, s(p), w_1^\ast)$, which is maximized by $p_1 = \bar{v} - rh_1 - q_C^* + q_C^*\alpha^2 r^2 h^2 h_1/\eta$. Further, we can show that the maximum profit of the retailer is $\gamma^\ast \pi_C^\ast - F$, which is lower than that when the retailer offers SA level $s_C^\ast$. Thus, the retailer will offer SA level $s_C^\ast$ to achieve the positive subsidy $F$. Similar to Xiao et al. [32], we can complete the proof.

**Proof of Corollary 1.** Differentiating $w_1^\ast$ with respect to $h$, we have

$$\frac{dw_1^\ast}{dh} = \frac{r}{2\eta(\bar{v} - c - rh)^2} \cdot \left\{ \eta[4F - (1 - \gamma)(\bar{v} - c - rh)^2 - 2Fhr(2\bar{v} - c - hr)] \right\}$$

which is positive if $\eta > \bar{\eta}_3$ and $F > (1 - \gamma)(\bar{v} - c - hr)^2/4$. Similarly, we can show the effect of the mismatching rate. Differentiating $w_1^\ast$ with respect to $\bar{v}$, we have

$$\frac{dw_1^\ast}{d\bar{v}} = \frac{1 - \gamma - \frac{F(2\eta - r^2h^2)}{\eta(\bar{v} - c - hr)^2}}{2}$$

which is negative if $F > \eta(1 - \gamma)(\bar{v} - c - hr)^2/[2(2\eta - r^2h^2)]$ because of $\eta > r^2h^2/2$.

**Proof of Proposition 4.** We can get that $\partial^2 \pi_{RA}/\partial s^2 = -(\eta - 2r^2\alpha b_1 h_R)$ . When $\eta > 2r^2\alpha b_1 h_R$, the second-order condition of $\pi_{RA}$ is satisfied. Solving the first-order condition

$$\partial \pi_{RA}/\partial s = r\alpha h_R(\bar{v} - m - w) - s\eta +rb_1[m - 2\alpha r h_R(1 - s)] = 0$$

we can get $s_A(m, w) = r[\alpha h_R(\bar{v} - m - w) + b_1(m - 2\alpha r h_R)]/(\eta - 2r^2\alpha b_1 h_R)$.

Inserting $s_A(m, w)$ into (6), we obtain $\pi_{MA}(m, w)$, which is a concave function of $w$ following from $\eta > 2r^2\alpha b_1 h_R$. Solving the first-order condition $\partial \pi_{MA}(m, w)/\partial w = 0$, we have

$$w_A(m) = \{(c - m + \bar{v})\eta + m^2b_1^2 - rb_1[crb_1 + r\alpha h_R(\bar{v} - m + \eta)]\}/[2(\eta - r^2\alpha b_1 h_R)]$$

Inserting it into $\pi_{RA}(m, w)$, we can get $\pi_{RA}(m)$.

Following from $\eta > 2r^2\alpha b_1 h_R$, the second-order condition of $\pi_{RA}(m)$ is equivalent to

$$f_1(\eta) = 4\eta^3 - 2r^2\alpha h_R(12b_1 + h_R\alpha)\eta^2 + 2r^4\alpha^2 b_1 h_R^2(5b_1 + \alpha h_R)\eta - r^6\alpha^2 b_1^2 h_R^2 h^2 > 0$$

By solving $d\pi_{RA}(m)/dm = 0$, we can obtain $m_A^\ast$, given by Proposition 4. Further, we can obtain the SPNE SA level, wholesale price and profits of both players. Note that the service level must be an interior point between 0 and 1.

**Proof of Proposition 5.** Under the TMSR mechanism $(m(w), t)$, the retailer should offer the manufacturer the unit wholesale price breakpoint $\bar{w} = p_C^\ast - m$.

Part (i) The second-order condition of the retailer’s profit $\bar{\pi}_{RA}$ over $s$ is $\partial^2 \bar{\pi}_{RA}/\partial s^2 = -(1 - t)\eta + 2r^2\alpha b_1 h_R$. When $r > 2r^2\alpha b_1 h_R/(1 - t)$, the profit function of the
retailer is a concave function of $s$. Solving the first-order condition $\partial \bar{\pi}_{RA}/\partial s = 0$, we can obtain

$$ s_{A1}(m, t, w) = r[\alpha h_{R}(\bar{v} - m - w) + \bar{b}_{1}(m - 2r\alpha h_{R})]/[(1 - t)\eta - 2r^{2}\alpha \bar{b}_{1}h_{R}]. $$

Solving $s_{A1}(m, t, p_{C}^{*} - m) = s_{C}^{*}$ for $m$, we have

$$ \bar{m}_{A}(t) = s_{C}^{*}(1 - t)\eta/(r\bar{b}_{1}) - \alpha h_{R}[\bar{v} - p_{C}^{*} - 2r\bar{b}_{1}(1 - s_{C}^{*})]/\bar{b}_{1}. $$

Now, we show that the manufacturer has an incentive to offer $p_{C}^{*} - \bar{m}_{A}(t)$. Inserting $\bar{m}_{A}(t)$ and $s_{C}^{*}$ into (8), we can obtain $\bar{\pi}_{MA}(w, t)$, which is a concave function of $w$. Solving $\partial \bar{\pi}_{MA}(w, t)/\partial w = 0$ for $w$, we obtain

$$ w_{A}(t) = \alpha h_{R}(\bar{v} - p_{C}^{*})/(2\bar{b}_{1}) + [c + \bar{v} - (2r\alpha h_{R} + r\bar{b}_{1})(1 - s_{C}^{*})]/2 - s_{C}^{*}(1 - t)\eta/(2r\bar{b}_{1}). $$

Thus, $w_{A}(t) - (p_{C}^{*} - \bar{m}_{A}(t)) = (\bar{v} - c - rh)(\bar{b}_{1} - th)\eta/[2\bar{b}_{1}(2\eta - r^{2}h^{2})]$, which is positive following from $\eta > r^{2}h^{2}/2$, $\bar{v} > c + rh$, and $0 < t < \bar{b}_{1}/h$. Further, the manufacturer has an incentive to charge the unit wholesale price equal to $p_{C}^{*} - \bar{m}_{A}(t)$ if the manufacturer wants to take $\bar{m}_{A}(t)$.

Part (ii) From Part (i), we see that the optimal SA level of the retailer is $s_{A1}(\bar{m}_{A}(t), t, p_{C}^{*} - \bar{m}_{A}(t)) = s_{C}^{*}$, given the unit wholesale price $p_{C}^{*} - \bar{m}_{A}(t)$ and the retailer’s profit margin $\bar{m}_{A}(t)$. Thus, the SA service commitment of the retailer is credible.

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