Hindawi
Mathematical Problems in Engineering
Volume 2018, Article ID 4717094, 20 pages
https://doi.org/10.1155/2018/4717094

Research Article

Fresh-Keeping Effort and Channel Performance in a Fresh Product Supply Chain with Loss-Averse Consumers' Returns

Bojun Gu,[1] **Yufang Fu**,[1] **and Yanling Li**[2]

[1] *School of Economics and Management, Zhejiang Ocean University, Zhoushan, China*
[2] *School of Marine Science and Technology, Zhejiang Ocean University, Zhoushan, China*

Correspondence should be addressed to Bojun Gu; gubojun@zjou.edu.cn

Received 22 April 2018; Revised 7 June 2018; Accepted 7 June 2018; Published 11 July 2018

Academic Editor: Vladimir Turetsky

We consider a fresh product supply chain consisting of one fresh product supplier and one e-tailer. Supplier sells fresh products through e-tailer in an online market, and the e-tailer offers a full-refund return policy to loss-averse consumers and exerts a fresh-keeping effort to keep the product at the optimum freshness level. By developing an analytical model, we derive the optimal price, quantity, and fresh-keeping effort jointly and verify that it is unique in the centralized setting. Based on the comparison, we demonstrate that the e-tailer's profit is greater with fresh-keeping effort than without it; therefore, the e-tailer has an incentive to engage in fresh-keeping effort. We also show that the return rate is independent of the fresh-keeping effort and consumers' loss aversion. In the decentralized setting, we first characterize the optimal wholesale price by the numerical study and then find that although the buyback contract still works, the revenue-sharing contract fails to achieve channel coordination under our model formulation. Furthermore, we develop a revenue- and cost-sharing contract that can coordinate the supply chain by designing a new contractual mechanism. Our numerical studies offer the Pareto improvement regions under the buyback and revenue- and cost-sharing contracts in which the supplier and e-tailer can earn more expected profits compared with being under wholesale price contract.

1. Introduction

With the development of e-commerce, the e-tailing of fresh (agricultural) products (e.g., live seafoods, fresh meats, fresh fruits, and fresh vegetables) has grown faster in the last ten years in China. The total transaction amounts to ¥139.13 billion in 2017 according to the monitoring data from the China e-Business Research Center (CeBRC). Although the market is growing fast, fresh product e-tailing is still in a big trouble, especially for the e-tailer. According to the CeBRC, in 2014, there are more than 4000 fresh product e-tailers in Chinese e-market, but only 1% of them yield a positive profit. Among various reasons, the poor cold-chain logistics and high return rate for the sales top the list of challenging tasks. For example, according to the monitoring data from the CeBRC, the average loss rate of fresh products is 25%-30% because of poor cold-chain logistics service, which leads to a loss of $8.9 billion sales annually in fruit and vegetable distribution. Moreover, for poor logistics service and fresh products' high perishable nature, purchasing fresh products online may seem riskier to the consumer, because they can not examine products physically and must rely only on the website description. Hence, consumers may be more hesitant to make a purchasing decision and more likely to return the product when it does not satisfy their expectation. It indicates that more fresh-keeping efforts by the e-tailer may lead to a lower return rate. Because such efforts can ensure the optimal freshness of fresh products during the total dispatching process and improve consumer satisfaction. Many e-tailers, such as jd.com, sfbest.com, and yiguo.com, have invested heavily in constructing cold-chain logistics to prevent products from spoiling and maintain freshness during the logistics process. In addition to fresh-keeping efforts, the refund price is another important factor that influences return rate. Obviously, a higher refund price will lead to a higher return rate.

From the perspective of e-tailers, decision to put forth more fresh-keeping effort is a choice of contradictions. On

one side, more fresh-keeping effort means greater freshness, leading to low consumer returns, which increases the sales revenue. On the other side, more fresh-keeping effort is costly, which decreases the sales revenue. Similarly, decision about price is also contradictory. A higher price means a higher profit margin of fresh products, increasing the sales revenue. However, a higher price will lead to more consumer returns when the e-tailer exerts a full-refund return policy, decreasing the sales revenue. Therefore, e-tailers should trade off the positive and negative effects of their fresh-keeping effort and price.

To that end, we develop an analytical model to consider a supply chain in which one supplier sells fresh products through one e-tailer in online market. We assume the e-tailer offers a full-refund return policy to consumers to reduce consumers' purchasing risk. Consumers are loss averse [1–4], which means they are more averse to losses than to equal gains. Therefore, when consumers who are loss averse receive fresh products, they may return less often than risk-neutral consumers; this is also called endowment effect [5, 6]. Given loss-averse consumers and full-refund return policies, the first goal of this paper is to capture the joint decisions of price, quantity, and fresh-keeping effort and also to investigate whether the supply chain has an incentive to exert a fresh-keeping effort in the centralized setting; the second goal is to examine supply chain contracts and channel performance in the decentralized setting.

Our main contributions are as follows. First, we construct an analytical model and derive the price, quantity, and fresh-keeping effort in the centralized and decentralized settings, offering a useful way to characterize the joint optimal decisions in the fresh product e-tailing market. Second, based on the comparison, we demonstrate that the e-tailer's profit is greater with fresh-keeping effort than without it. Therefore, the e-tailer has an incentive to engage in fresh-keeping effort. Third, we find that the return rate is independent of the fresh-keeping effort and consumers' loss aversion. Finally, we develop a new coordination contract by designing a new contractual mechanism and capture the Pareto improvement region for the supplier and e-tailer under coordinating conditions.

The remainder of this paper is organized as follows. In Section 2, we review the relevant literature. In Section 3, we formulate our model and outline main assumptions. In Section 4, we first characterize the joint optimization in a centralized setting and then make a comparison and sensitive analysis. In Section 5, we first investigate the optimal decisions for the supplier and e-tailer, respectively, in a decentralized setting and then examine supply chain contracts and channel performance. Finally, concluding remarks and some directions for future work are given in Section 6.

2. Literature Review

Our study is related to three steams of literature: quality improvement and supply chain coordination, customer return, and loss-averse preference.

The first stream of research related to our paper is quality improvement and supply chain coordination. Assuming the market demand depends on fresh-keeping effort, Cai et al. [7] examine optimal decisions of the fresh-keeping effort, order quantity, and price in a fresh product supply chain. They demonstrate that a price-discount sharing mechanism together with a compensation scheme coordinates the distributor's fresh-keeping effort and achieves channel coordination. By investigating a similar problem to Cai et al. [7], Wu et al. [8] investigate the joint decision of price, order quantity, and logistics service level in the three power balance scenarios. They show that revenue and service-cost-sharing contract and price-discount and inventory-risk sharing contract both can achieve channel coordination. Based on a deterministic demand which depends on the logistics service level and price, Yu and Xiao [9] characterize the pricing and logistics service level decisions of a fresh agriproducts supply chain. Xu [10] considers the joint optimization of price and quality based on a quality-dependent demand function in a distribution channel in which the manufacturer sets the wholesale price and quality simultaneously and retailer sets the price; finding the quality decision is affected by the marginal revenue function. Xie et al. [11] also examine the optimal quality investment and pricing decisions in a make-to-order supply chain based on a quality-dependent demand function; however, they assume the supply chain members are risk averse. Jerath et al. [12] assuming the target demand is a fraction of potential stochastic demand and the fraction is determined by the quality and the retailer price, establish an analytical model to capture optimal price, quality, and order quantity in a centralized setting. The model shows that the buyback, quantity discount, revenue-sharing, and two-part contracts all can achieve channel coordination in a decentralized setting based on a responsive price. Leng et al. [13] explore the retailer's price and quality gatekeeping effort for a manufacture-retailer channel based on a price and quality-dependent demand function. By constructing an inverse demand function which depends on product's emission abatement level, Yang and Chen [14] investigate the impacts of revenue-sharing and cost-sharing on manufacture's carbon emission abatement efforts. They reveal that cost-sharing becomes dispensable when both revenue-sharing and cost-sharing are available.

Generally, when in an offline market, consumers examine products physically and make purchasing decisions by trading off the price and quality (freshness). Hence, they assume the demand is dependent on quality or fresh-keeping effort but not on a consumer's return factor. When in an online market, the contrary is true. Consumers cannot be assured of the freshness of products when making a purchasing decision; thus, we assume the demand is independent of freshness and fresh-keeping effort but dependent on consumer returns.

Second stream is related to consumer returns. Modeling the return rate by uncertain valuation was previously studied by Che [15] and Davis et al. [16]. Che [15] assumes customers are risk averse and applies the von-Neumann utility function to model customers' preference; and Davis et al. [16] model customers' uncertain valuation by using a Bernoulli random variable. Recently, Su [17] examines the full returns and partial returns in a newsvendor model in which the return rate depends on the valuation of product and refund price,

and the stochastic demand is independent of price. Assuming refund and price are determined exogenously and are not decision variables, Xiao et al. [18] use a similar method for modeling the return rate and examine the buyback and markdown contracts. Similarly, Chen and Bell [19] also capture the impact of full returns policies on order quantity decisions and buyback contracts. Assuming the stochastic demand is price dependent, Hu et al. [20] reveal the impact of full returns policies on decentralized supply chain under consignment contracts in which the return rate is also dependent on refund price and customer's uncertain valuation of products. There are still some different methods for modeling customer returns. For example, Chen and Bell [21] and Chen and Bell [22] assume customer returns are a function of quantity sold and refund price; Vlachos and Dekker [23], Mostard and Teunter [24], Ruiz-Benitez and Muriel [25], Chen and Zhou [26], Chen and Chen [27], and Choi and Guo [28] model customer returns are a fixed proportion of quantity sold; Yoo et al. [29] assume consumer returns are an increasing linear function of the refund price. However, the above research all assumes the customer is risk neutral except Che [15].

Third, our article relates to the loss-averse preference. Since Kahneman and Tversky [30] have proposed prospect theory, the loss-averse value function has been used to identify ordering policy [31–33] and supply chain contracts [34]. The value function in these researches is applied to evaluate total outcomes; this means the total outcomes are perceived as gain or loss in relation to a reference point. It is theoretical to formulate the elementary outcomes in single account; but for compound outcomes it can be framed in different ways which is called psychological account (later, Tversky and Kahneman [35] call it mental account) [36]. Thaler [37] and Thaler [38] extend the value function to evaluate compound outcomes and show that mental accounting matters. In operation management, Ho and Zhang [39] first use multiple mental accounts to formulate the two-part tariff contract and provide a behavioral model based on loss-averse value function to investigate the channel efficiency. Later, in stochastic demand scenarios, Beckerpeth et al. [40] explore buyback contracts by formulating newsvendor outcomes as sales revenue and overage cost, confirming that contracts designed using the behavioral model perform better than contracts designed using the standard model. Based on multiple mental accounts, Davis et al. [41] consider the push contract, pull contract, and advance purchase discount contract, showing that behavioral model which combines loss aversion with errors accurately predicts channel efficiency and qualitatively matches decisions. Similarly, Zhang et al. [42] formulate the different sequence and magnitude of costs and revenues into different accounts and examine the contract preferences between buyback and revenue-sharing contract for a loss-averse supplier; the results are consistent with the behavioral tendency of loss aversion. Assuming customers are loss aversion, Samatli-Pac and Shen [43] develop a return rate by using loss-averse value function and uncertain valuation but formulate the value function by a single account. Liao and Li [44] also investigate loss-averse customer's return. In their research, loss-averse value function is formulated by a single account and is only used to analyze the market demand.

Table 1 provides summary of the related literature. In the aforementioned literature, no model is proposed to consider fresh-keeping effort, loss-averse customer return, and mental accounting simultaneously. Therefore, our research difference from the first stream of literature is that we assume the customer demand is related to customer returns, but they assume customer demand is quality dependent. We differ from the second stream of literature as we formulate the customer's uncertain value by loss-averse value function, but they assume the customer is risk neutral or risk averse. We differ from the third stream of literature as we use multiple mental accounts to formulate the loss-averse customer's value function and to model return rate, but they use multiple mental accounts to formulate the retailer's or supplier's loss-averse value function and focus on retailer's or supplier's utility function.

3. Model Formulation and Assumption

We consider a two-echelon fresh product supply chain in which one supplier sells fresh products through one e-tailer in an online market by retail price p. To decrease the consumers' purchasing risk and increase sales revenue in the online market, e-tailer offers a full-refund return policy to consumers. When e-tailer offers a full-refund return policy to the consumer, consumer's online purchasing decision can be divided into two stages. In the first stage, noted as purchasing stage, consumer decides whether to buy the fresh product at retail price p based on the product information depicted by the website. In the second stage, named as returning stage, consumer who has purchased the fresh product online decides whether to keep or return the product after receiving it from the express delivery and experiencing it firsthand [17]. This means consumers can return the fresh product they have purchased online and receive the full refund p if they are not satisfied with the freshness of the product after receiving it from express delivery. Meanwhile, the e-tailer exerts a fresh-keeping effort t ($t \geq 0$) to improve freshness of products, which means that $\theta = \theta(t)$ is increasing in t. The online market demand X is stochastic and has CDF $F(x)$ and PDF $f(x)$ in the region $[A, B]$ with $B > A > 0$.

This dyadic supply chain is formulated as Figure 1. Before selling season, the supplier is considered as a dominator who offers supply chain contracts to e-tailer first; e-tailer is considered as a follower and sets the price p, order quantity q, and fresh-keeping effort t simultaneously based on the contractual arrangement subsequently. Then, the demand is realized and $\min(x, q)$ quantity of fresh products are sold in selling season. If the consumer decides to keep the fresh product, the deal is closed at this stage; but if the consumer returns the fresh product he received because of dissatisfaction, e-tailer pays the full refund p to the consumer. At the end of selling season, the overage order quantity is salvaged by e-tailer or supplier, depending on the different types of contracts. We assume returned fresh products from consumers have no salvage value and cannot be resold. This is consistent with the practice of the fresh product e-tailing

Table 1: Summary of the related literature.

Authors	Quality dependent demand	Main decision variable	Types of contract	Contract coordination
Part A: Summary of literature about quality improvement and supply chain coordination				
Cai et al. [7]	√	Fresh-keeping effort, order quantity, price	Price-discount sharing contract together with compensation contract	√
Wu et al. [8]	√	Logistics-service level, order quantity, price	Revenue and service-cost sharing contract, price-discount and inventory-risk sharing contract	√
Yu and Xiao [9]	√	Price, logistics-service level	Wholesale price contract	
Xu [10]	√	Price, quality	Wholesale price contract	
Xie et al. [11]	√	Quality investment, price	Wholesale price contract	
Jerath et al. [12]	√	Price, quality, order quantity	Buyback contract, quantity discount contract, revenue sharing contract and two-part contract	√
Leng et al. [13]	√	Price, quality gatekeeping effort	Wholesale price contract	
Yang and Chen [14]	√	Carbon emission abatement effort, quantity	Wholesale price contract, cost sharing contract, revenue sharing contract, revenue and cost sharing contract	

Authors	Modeling forms of consumer' return rate	Customer's risk preference
Part B: Summary of literature about customer return		
Che [15]	Uncertain valuation	Risk averse
Davis et al. [16]	Uncertain valuation	Risk neutral
Su [17]	Uncertain valuation	Risk neutral
Xiao et al. [18]	Uncertain valuation	Risk neutral
Chen and Bell [19]	Uncertain valuation	Risk neutral
Hu et al. [20]	Uncertain valuation	Risk neutral
Chen and Bell [21], Chen and Bell [22]	A function of quantity sold and refund price	Risk neutral
Vlachos and Dekker [23], Mostard and Teunter [24], Ruiz-Benitez and Muriel [25], Chen and Zhou [26], Chen and Chen [27], Choi and Guo [28],	A fixed proportion of quantity sold	Risk neutral
Yoo et al. [29]	An increasing linear function of the refund price	Risk neutral

Authors	Loss-averse individual	Single account	Multiple mental accounts	Consumer return
Part C: Summary of literature about loss-averse preference				
Schweitzer and Cachon [31]	retailer	√		
Wang and Webster [32]	retailer	√		
Wang [33]	retailer	√		
Wang and Webster [34]	retailer	√		
Ho and Zhang [39]	retailer		√	
Beckerpeth et al. [40]	newsvendor		√	
Davis et al. [41]	retailer		√	
Zhang et al. [42]	supplier		√	
Samatli-Pac and Shen [43]	customer	√		√
Liao and Li [44]	customer	√		√

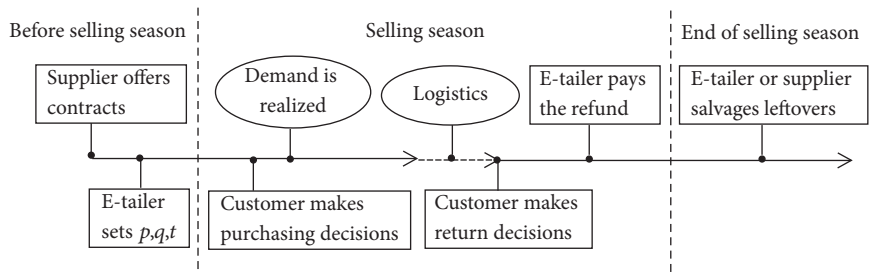

Figure 1: Timeline of events under consideration.

because fresh products decay easily due to poor reverse logistics. Let c be the manufacturing cost for supplier. Let s be the salvage value for e-tailer or suppler. Let $S(q)$ be the expected sales.

3.1. Freshness Function with Fresh-Keeping Effort. More fresh-keeping effort could result in fresher products, and the higher the freshness, the more the fresh-keeping effort that should be exerted to improve the products' freshness. Therefore, we use continuously differentiable concave function as the freshness function $\theta(t) = \theta_0 + \alpha t^{1/\beta}$, where $\theta_0 > 0$, $\alpha > 0$, and $\beta > 1$. θ_0 is interpreted as the initial freshness of fresh products when e-tailer does not exert any fresh-keeping effort. α is a scalar parameter [45, 46], and $\beta > 1$ is to ensure the freshness function's concavity.

3.2. Cost Function with Fresh-Keeping Effort. More fresh-keeping effort will lead to higher costs, and the more the fresh-keeping effort, the higher the cost that is needed to increase the fresh-keeping effort. Therefore, we use the continuously differentiable convex function as the cost function $c(t) = c_0 t^{\gamma}$, where $c_0 > 0$ and $\gamma \geq 2$. c_0 is a scalar parameter [45, 46] and $\gamma \geq 2$ is to ensure the freshness function's convexity. Several studies (e.g., Xie et al. [11], Li et al. [46], and Cachon and Lariviere [47]) use the second differentiable convex function to depict cost structure; hence, our cost function is more common and could cover them.

3.3. Return Rate with a Loss-Averse Consumer. Because the fresh product was purchased online, the consumer can be assured of the freshness of the fresh product only in returning stage (called postpurchase value). Therefore, the retail price p, which the consumer paid during purchasing stage, is a sunk cost to the consumer during returning stage. Whether the consumer will return the fresh product depends on the postpurchase value and full refund p but is independent of the retail price p. Assume the consumer is heterogeneous and values the freshness $\theta(t)$ by a random variable y individually. Therefore, a risk-neutral consumer will return the fresh product if postpurchase value $y\theta(t)$ is less than full refund p; i.e., $y\theta(t) < p$ [17, 20].

Here, we assume the consumer is loss averse and has a piecewise-linear utility function $v(\pi) = \begin{cases} \pi & \pi > 0 \\ \lambda\pi & \pi \leq 0 \end{cases}$, where $\lambda > 1$ implies the loss-averse coefficient [31]. We also assume the utility function $v(\cdot)$ is formulated by multiple mental accounts. This means the utility function will be applied to evaluate each account [38]. Thus, given postpurchase value $y\theta(t)$ and full refund p, when $U(t, p) = v(-y\theta(t)) + v(p) = -\lambda y\theta(t) + p > 0$, the consumer will return the product. Let the return rate equal R and assume the random variable y follows uniform distribution and has CDF $G(y)$ when $y \in [0, 1]$; then $R = G[p/(\lambda\theta(\tau))] = p/(\lambda\theta(\tau))$.

Our definition of return rate is similar to that of Che [15], Su [17], Hu et al. [20], and Samatli-Pac and Shen [43]; however, they all assume $\theta(t)$ is constant and determined exogenously. If $\lambda = 1$, our return rate reduces to $G(p/\theta)$ and is equal to that of Su [17] and Hu et al. [20]. If $v(\pi)$ is a von-Neumann utility function, our return rate is also equal to that of Che [15]. When the piecewise-linear utility function $v(\cdot)$ is formulated by a single account, our return rate is also equal to that of Samatli-Pac and Shen [43].

Based on above formulation, we will consider the supply chain in a centralized setting and decentralized setting, respectively. In the centralized setting, we are to examine the optimal price, stocking quantity, and fresh-keeping effort simultaneously for a central decision maker and to verify whether the central decision maker has an incentive to exert a fresh-keeping effort. In the decentralized setting, we will consider supply chain contracts and design contractual mechanisms to achieve channel coordination. In this paper, the superscript cc represents the supply chain in centralized conditions, and wp, bb, rs, and rc stand for the wholesale price, buyback, revenue-sharing, and revenue- and cost-sharing contracts in a decentralized channel, respectively. The subscripts E and S represent e-tailer and supplier, respectively; the subscript N represents the case without fresh-keeping effort.

4. Joint Optimization in a Centralized Setting

In the centralized supply chain, we suppose supplier and e-tailer form one central decision maker. To focus our research on the online market, we investigate joint optimization in a centralized setting from the perspective of an e-tailer. This means e-tailer is the central decision maker and manages both the manufacturing function and e-tailing function. This model resembles a classic newsvendor model. Given the manufacturing cost c, e-tailer chooses price p, stocking quantity q, and fresh-keeping effort t simultaneously, and the expected profit of the e-tailer is as follows:

$$E\pi_E^{cc}(p, q, t) = p\left[1 - G\left(\frac{p}{\lambda\theta(t)}\right)\right] S(q) + s[q - S(q)] - cq - c(t)$$

$$= p\left[1-\frac{p}{\lambda\theta(t)}\right]S(q)+s[q-S(q)] - cq - c(t) \quad (1)$$

Assumption 1. $p[1-p/(\lambda\theta(t))]-c>0$.

Assumption 2. Let $h(x)=f(x)/[1-F(x)]$; $h(x)$ is increasing in x, when $x\in(0,+\infty)$.

Assumption 1 means the manufacturing cost c should not be larger than $p[1-p/(\lambda\theta(\tau))]$ to ensure e-tailer yields a positive profit. And Assumption 2 shows the demand distribution should satisfy the *increasing failure rate* (IFR) condition. IFR is a common and mild assumption. PF2 distributions and the log-normal distribution all satisfy IFR [48, 49].

In order to explore if e-tailer has an incentive to exert fresh-keeping efforts, we provide the comparisons among the cases with and without fresh-keeping effort. We denote the case in which e-tailer does not exert a fresh-keeping effort as a benchmark. And, given $t=0$, the expected profit of e-tailer is as follows:

$$E\pi_{EN}^{cc}(p,q)=p\left[1-\frac{p}{\lambda\theta_0}\right]S(q)+s[q-S(q)]-cq \quad (2)$$

Now, we first derive the optimal solution (p,q) for the e-tailer under the case without fresh-keeping effort, which is given in Proposition 3.

Proposition 3. *(i) Letting $t=0$, given any fixed q, $E\pi_{EN}^{cc}(p\mid q)$ is concave in p; the optimal retail price p_N^{cc*} is unique and given by*

$$p_N^{cc*}=\frac{\lambda\theta_0}{2}. \quad (3)$$

(ii) Given Assumption 1, $E\pi_{EN}^{cc}(q)$ is a concave function in the region $[A,B]$; the optimal quantity q_N^{cc*} is unique and given by

$$F(q_N^{cc*})=\frac{\lambda\theta_0-4c}{\lambda\theta_0-4s}. \quad (4)$$

Proof. See Appendix. □

We denote the optimal solution as ψ_1, that is, $\psi_1=(p_N^{cc*},q_N^{cc*})$, and the maximized expected profit for e-tailer is $E\pi_{EN}^{cc}(p_N^{cc*},q_N^{cc*})$.

And then we investigate the case in which e-tailer exerts a fresh-keeping effort and derive the optimal solution (p,q,t) for e-tailer, which is given in Proposition 4.

Proposition 4. *(i) Given any fixed q and t, $E\pi_E^{cc}(p\mid q,t)$ is concave in p; the optimal retail price $p^{cc*}(t)$ is unique and given by*

$$p^{cc*}(t)=\frac{\lambda\theta(t)}{2}. \quad (5)$$

(ii) For (5), given any fixed q, $E\pi_E^{cc}(p^{cc*}(t),t\mid q)$ is concave in t; the optimal fresh-keeping effort $t^{cc*}(q)$ is unique and given by

$$t^{cc*}(q)=\left[\frac{\lambda aS(q)}{(4c_0\gamma\beta)}\right]^{\beta/(\gamma\beta-1)}. \quad (6)$$

(iii) For (5) and (6), given Assumptions 1 and 2, $E\pi_E^{cc}(t^{cc*}(q),p^{cc*}(q),q)$ is an unimodal function in the region $[A,B]$; the optimal quantity q^{cc*} is unique and satisfies

$$\left[\frac{\lambda\theta_0-4s}{4}+\frac{\lambda a}{4}\left(\frac{\lambda aS(q^{cc*})}{4\beta c_0\gamma}\right)^{1/(\gamma\beta-1)}\right][1-F(q^{cc*})] - c+s=0. \quad (7)$$

Proof. See Appendix. □

Given (5), (6), and (7), we can obtain optimal quantity q^{cc*}, optimal fresh-keeping effort $t^{cc*}=t^{cc*}(q^{cc*})$, and optimal price $p^{cc*}=p^{cc*}(t^{cc*}(q^{cc*}))$. We denote optimal solution as ψ_2, that is, $\psi_2=(p^{cc*},q^{cc*},t^{cc*})$, and the maximized expected profit for e-tailer is $E\pi_E^{cc}(p^{cc*},q^{cc*},t^{cc*})$.

Next, we provide the comparison between the maximized expected profits of e-tailer with and without fresh-keeping effort, depicted as Proposition 5.

Proposition 5. *Under the centralized setting, $p^{cc*}>p_N^{cc*}$, $q^{cc*}>q_N^{cc*}$ and $E\pi_E^{cc}(p^{cc*},q^{cc*},t^{cc*})>E\pi_{EN}^{cc}(p_N^{cc*},q_N^{cc*})$.*

Proof. See Appendix. □

Proposition 5 implies that, comparing with no fresh-keeping effort, if e-tailer makes efforts to keep the product fresh, profits of e-tailer can be improved. Therefore, e-tailer has an incentive to engage in fresh-keeping effort. Because $p^{cc*}>p_N^{cc*}$ and $q^{cc*}>q_N^{cc*}$, the profit margin, especially, the sales revenue, is improved. As long as the increment of sales revenue is larger than the increasing amount of cost of fresh-keeping effort, we have $E\pi_E^{cc}(p^{cc*},q^{cc*},t^{cc*})>E\pi_{EN}^{cc}(p_N^{cc*},q_N^{cc*})$; this may be the intuitive explanation to Proposition 5.

Let $(p-c)/p>0.5$ be the high profit product and $(p-c)/p\le 0.5$ be the low-profit product. Assumption 1 means that Propositions 3, 4, and 5 only work for high profit products, when the fresh product has low profit, i.e., $(p-c)/p\le 0.5$, leading to $p^{cc*}(t)[1-p^{cc*}(t)/(\lambda\theta(t))]-c\le 0$. Under this condition, e-tailers cannot earn a positive profit under our model formulation. This depicts the obstacles encountered in fresh product e-commerce in China currently. To offer high-freshness products, fresh product e-tailers have to spend quite a bit to improve the cold-chain logistics. However, most fresh products have low profit. The limited price margins are not able to offset high dispatch costs, leading to a loss for most fresh product e-tailers as addressed in the first part of this paper. According to our model formulation, fresh product e-tailers should focus on high profit products, such as organic produce and high-value fresh products, to increase price margins and earn a positive profit.

According to our knowledge, some fresh product e-tailers in China, such as MR.FRESH, sfbest.com, womai.com, and www.tootoo.cn, have changed their strategy and switched to high profit fresh products.

In order to offer further insights, we make some sensitivity analysis and a numerical study in the centralized setting, shown as follows.

Corollary 6. *Return rate R is independent of t and λ and equals 0.5.*

Given y follows uniform distribution in the support $[0, 1]$ and the return rate $R = 0.5$ and is independent of t and λ because $p^{cc*}(t) = \lambda\theta(t)/2$ and $R = p^{cc*}(t)/(\lambda\theta(\tau))$. The proof is simple; hence, we omit it. The main reason is that when e-tailers exert a fresh-keeping effort to improve the freshness of products, they will increase retail price to increase price margins. Since the return rate R is increasing in the full refund and decreasing in freshness of products, the negative effect equals the positive effect, because of the linear probability density function of the uniform distribution.

Corollary 7.

(i) *The optimal order quantity $q^{cc*}(t)$ is increasing in t, i.e., $dq^{cc*}(t)/dt > 0$.*

(ii) *The optimal price $p^{cc*}(t)$ is increasing in t, i.e., $dp^{cc*}(t)/dt > 0$.*

Proof. See Appendix. □

When e-tailer exerts a fresh-keeping effort, more fresh-keeping effort implies fresher products, inducing e-tailer to set a higher price and a higher order quantity. Therefore, efforts to keep products fresher can increase profit margins and can also increase expected sales revenue. Let $\Pi(t) = (1-R)p^{cc*}(t)S(q^{cc*}(t))$ be the expected net sales revenue given any fixed t. Since the return rate R is independent of t and λ, the expected net sales revenue is also increasing in fresh-keeping effort. Thus, it also supports e-tailer to exert a fresh-keeping effort, which is consistent with Proposition 5.

Corollary 8.

(i) $dq^{cc*}/d\lambda > 0$; $dt^{cc*}/d\lambda > 0$; $dp^{cc*}/d\lambda > 0$; $d\Pi(t^{cc*})/d\lambda > 0$.

(ii) $dq^{cc*}/ds > 0$; $dt^{cc*}/ds > 0$; $dp^{cc*}/ds > 0$; $d\Pi(t^{cc*})/ds > 0$.

(iii) $dq^{cc*}/d\theta_0 > 0$; $dt^{cc*}/d\theta_0 > 0$; $dp^{cc*}/d\theta > 0$; $d\Pi(t^{cc*})/d\theta_0 > 0$.

(iv) $dq^{cc*}/dc < 0$; $dt^{cc*}/dc < 0$; $dp^{cc*}/dc < 0$; $d\Pi(t^{cc*})/dc < 0$.

Proof. See Appendix. □

Comparing with consumers who are risk neutral, when consumers are loss averse, e-tailer will engage in more fresh-keeping efforts and will also set a higher price and order more. When the consumer receives fresh product, he or she considers the return as a loss and refund as a gain in returning stage. Because of loss aversion, the consumer will value the fresh product more than risk-neutral consumer if he or she returns it. Therefore, e-tailer will set higher price when dealing with loss-averse consumers. Although this may be counterintuitive, it is consistent with the findings in the literature [5]. Further, because of the loss aversion of consumers, the expected net sales revenue $\Pi(t^{cc*})$ is higher compared with selling to risk-neutral consumers. Thaler [5] also states that given a two-week trial period with a money back guarantee, the sale is more likely for endowment effect. Therefore, a full-refund return policy benefits e-tailer more when the consumer is loss averse compared with selling to risk-neutral consumer in the online market. Moreover, q^{cc*}, t^{cc*}, p^{cc*}, and $\Pi(t^{cc*})$ are all increasing in s and θ_0 but decreasing in c. An intuitive explanation is that, as s and θ_0 increases, e-tailer benefits more by decreasing overordering cost and increasing profit margin, which results in a larger order quantity, more fresh-keeping effort and a higher price, and also a larger expected net sales revenue subsequently. However, a larger c may shrink the profit margin, leading to opposite side. Thus, it offers a guideline for e-tailer about how to change the optimal decision according to the key model inputs.

Next, we will use numerical experiments to provide the impact of loss aversion λ, salvage value s, initial freshness θ_0, and purchasing cost c on the expected profit $E\pi_E^{cc*} = E\pi_E^{cc}(p^{cc*}, q^{cc*}, t^{cc*})$. Set $c = 5$, $s = 1$, $\theta_0 = 20$, $a = 2$, $\beta = 2$, $\gamma = 2$, $c_0 = 3$, and $\lambda = 2$. Let $F(x)$ follow truncated norm distribution in the region $x \in (0, +\infty)$; therefore, $F(x) = [I(x) - I(0)]/[1 - I(0)]$, where $I(x)$ is a norm distribution with mean $\mu = 200$ and standard deviation $\sigma = 50$. Table 2 lists the expected profit changing with λ, s, θ_0, and c, respectively.

Table 2 shows that the expected profit of e-tailer is increasing in λ, s, and θ_0, respectively, but decreasing in c. Therefore, our numerical results are directly consistent with Corollary 8, in which the sensitivity of optimal decision to λ, s, θ_0, and c is the same as the expected profit to λ, s, θ_0, and c. The e-tailer can increase profits by choosing more loss-averse consumers and increasing the salvage value and initial freshness of the fresh products and also can increase profits by decreasing the purchasing cost of fresh products.

5. Joint Optimization in a Decentralized Setting and Channel Performance

Here, we consider the supply chain in a decentralized setting and examine wholesale price, buyback, and revenue-sharing and revenue- and cost-sharing contracts, respectively. By treating $(p^{cc*}, q^{cc*}, t^{cc*})$ as the first best solution, our purpose is to design a contractual mechanism and to achieve supply chain coordination. We also examine whether the Pareto improvement is possible in the coordinated setting with contracts, even when the supply chain is affected by consumer returns, consumers' loss aversion, and fresh-keeping efforts.

5.1. Wholesale Price Contracts. Under the wholesale price contract, supplier first sets the wholesale price w, and then e-tailer in response sets the price p, order quantity q, and

Table 2: Effects of λ, s, θ_0, and c on the expected profit of e-tailer.

λ	$E\pi_E^{cc*}$	s	$E\pi_E^{cc*}$	θ_0	$E\pi_E^{cc*}$	c	$E\pi_E^{cc*}$
1.1	177.0	0.6	1158.3	16	797.1	3	1635.4
1.2	276.8	0.7	1161.2	17	889.7	3.5	1513.9
1.3	380.7	0.8	1164.3	18	982.8	4	1396.1
1.4	487.8	0.9	1167.3	19	1076.4	4.5	1281.7
1.5	597.4	1	1170.4	20	1170.4	5	1170.4
1.6	709.0	1.1	1173.5	21	1264.7	5.5	1062.1
1.7	822.3	12	1176.7	22	1359.4	6	956.6
1.8	937.1	1.3	1180.0	23	1454.4	6.5	853.9
1.9	1053.2	1.4	1183.3	24	1549.6	7	754.0
2.0	1170.4	1.5	1186.7	25	1645.0	7.5	656.9

fresh-keeping effort t jointly. Therefore, e-tailer's expected profit is

$$E\pi_E^{wp}(p,q,t \mid w^{wp}) = p\left[1 - G\left(\frac{p}{\lambda\theta(t)}\right)\right]S(q) + s[q - S(q)] - w^{wp}q - c(t). \tag{8}$$

Based on Proposition 4 and (8), we can obtain the joint optimal decision for e-tailer straightforwardly just substituting w^{wp} as c, denoted as $\psi_3 = (p^{wp*}, q^{wp*}, t^{wp*})$. That is,

$$\left[\frac{\lambda\theta_0 - 4s}{4} + \frac{\lambda a}{4}\left(\frac{\lambda a S(q^{wp*})}{4c_0\gamma\beta}\right)^{1/(\gamma\beta-1)}\right] \cdot [1 - F(q^{wp*})] - w^{wp} + s = 0, \tag{9}$$

$$t^{wp*} = \left(\frac{\lambda a S(q^{wp*})}{4c_0\gamma\beta}\right)^{\beta/(\gamma\beta-1)}, \tag{10}$$

$$p^{wp*} = \frac{\lambda\theta(t^{wp*})}{2}. \tag{11}$$

Corollary 8 states that optimal order quantity q^{cc*}, optimal price p^{cc*}, and optimal fresh-keeping effort t^{cc*} are all decreasing in c; therefore, when the supplier offers a single wholesale price w^{wp} to e-tailer in the decentralized supply chain, e-tailer will order less, set lower price, and exert fewer fresh-keeping efforts for $w^{wp} > c$, rendering the entire supply chain suboptimal.

Then, we will turn to the supplier's decision. Knowing e-tailer's self-interested order quantity q^{wp*}, the supplier's expected profit is

$$E\pi_S^{wp}(w^{wp}, q^{wp*}) = (w^{wp} - c)\,q^{wp*}. \tag{12}$$

Unfortunately, it is impossible to obtain the optimal wholesale price w^{wp*} analytically for (12) even when the stochastic demand X follows a uniform distribution. Therefore, we analyze it using a numerical method and show our findings as follows.

From Proposition 4, the value of w^{wp} should satisfy $(\lambda\theta_0 + \lambda a t^{1/\beta})/4 \geq w^{wp}$ in the decentralized channel given any $t \geq 0$ and $x > 0$; therefore, $\lambda\theta_0/4 \geq w^{wp}$. Obviously, c is the lower bound of w^{wp}. Similar to the numerical studies in Section 4, we compute supplier's and retailer's expected profit as well as the channel's total expected profit in the decentralized setting when w^{wp} varies from c to $\lambda\theta_0/4$ by step 0.1, shown in Figure 2.

From Figure 2, the expected profit $E\pi_S^{wp}(w^{wp}, q^{wp*})$ of supplier is increasing in w^{wp} in the region $[c, \lambda\theta_0/4]$; hence, the optimal wholesale price is $w^{wp*} = \lambda\theta_0/4 = 10$. When $w^{wp*} = 10$, the supplier's expected profit $E\pi_S^{wb*} = E\pi_S^{wb}(q^{wp*}, w^{wp*})$ and e-tailer's expected profit $E\pi_E^{wb*} = E\pi_E^{wb}(p^{wp*}, q^{wp*}, t^{wp*}, w^{wp*})$ are 795.0651 and 216.4, respectively, and the channel's total expected profit $E\pi_S^{wb*} + E\pi_E^{wb*}$ is 1011.5. Similar to the analytical results addressed above, numerical studies also show that the channel's total expected profit in decentralized setting is less than it is in centralized setting, where the channel's total expected profit $E\pi_E^{cc*}$ is 1170.4. This means the channel's efficiency under wholesale price contract in decentralized setting is only 86.42%. The result shows that the channel cannot be totally coordinated by pure wholesale price contract.

5.2. Buyback Contracts. Under buyback contract (w^{bb}, b), supplier first sets w^{bb} and b, and then e-tailer in response sets the price p, order quantity q, and fresh-keeping effort t to maximize expected profits. For the buyback contract, e-tailer can return the overage order to supplier and receive a buyback price b per unit; but, for consumer's return, assume e-tailer cannot return it to supplier. Based on the above formulation, the e-tailer's expected profit is

$$E\pi_E^{bb}(p,q,t \mid w^{bb}, b) = p\left[1 - G\left(\frac{p}{\lambda\theta(t)}\right)\right]S(q) + b[q - S(q)] - w^{bb}q - c(t). \tag{13}$$

Given buyback contract, we first derive the optimal price, order quantity, and fresh-keeping effort similar to Proposition 4, denoting the joint optimal decision as $\psi_4 = (p^{bb*}, q^{bb*}, t^{bb*})$, and then letting $\psi_4 = \psi_2$ we have Proposition 9.

Proposition 9. *Given*

$$w_{\max} = \frac{\left[sF\left(q^{cc*}\right) - c\right]/F\left(q^{cc*}\right) - \left[c\left(t^{cc*}\right) - (1/4)\,\lambda\theta\left(t^{cc*}\right)S\left(q^{cc*}\right)\right]/\left[q^{cc*} - S\left(q^{cc*}\right)\right]}{q^{cc*}/\left[q^{cc*} - S\left(q^{cc*}\right)\right] - 1/F\left(q^{cc*}\right)}, \tag{14}$$

and $b = [w^{bb} - c + sF(q^{cc*})]/F(q^{cc*})$, *for* $w^{bb} \in (c, w_{\max})$, *buyback contracts* (w^{bb}, b) *can coordinate the supply chain and allocate the profit between e-tailer and supplier arbitrarily.*

Proof. See Appendix. □

Pasternack [50] shows that buyback contracts can coordinate a common dyadic supply chain when retail price is exogenously determined. When retail price is endogenously determined, Bernstein and Federgruen [51] reveal that buyback contracts cannot coordinate the supply chain. Su [17] also examines the coordinating mechanism of the buyback contract, but he illustrates that it fails to achieve channel coordination when e-tailer offers return policies to consumer. However, when e-tailer offers a full-refund return policy to consumers, the supplier can still use buyback contracts to induce the e-tailer to choose the first best solution and achieve channel coordination if e-tailer exerts a fresh-keeping effort. Proposition 9 also demonstrates that the supplier can adjust the profit between e-tailer and himself by choosing different wholesale price. Thus, buyback contract in our model which coordinates three decision variables, i.e., price, order quantity, and fresh-keeping effort, is still simple and easy to be implemented as it is designed by Pasternack [50] which coordinates only one decision variable, i.e., order quantity.

Based on Proposition 9, taking the derivative of b with respect to λ, Corollary 10 can be obtained.

Corollary 10. *Buyback price b is decreasing in* λ.

Proof. See Appendix. □

Corollary 10 shows that the buyback price is lower when dealing with loss-averse consumers than when dealing with risk-neutral consumers. In other words, it is easy to coordinate e-tailer for suppliers by using buyback contracts when e-tailers face loss-averse consumers.

Setting wholesale price contract as a benchmark, we now examine whether the buyback contract can achieve the Pareto improvement, which means supplier and e-tailer both can obtain more expected profits under better coordination.

Let $\Delta E\pi_E^{bb} = E\pi_E^{bb*} - E\pi_E^{wb*}$, and $\Delta E\pi_S^{bb} = E\pi_S^{bb*} - E\pi_S^{wb*}$.

We adopt the same values of parameters as in Section 4 and depict $\Delta E\pi_E^{bb}$ and $\Delta E\pi_S^{bb}$ as changing with w^{bb} as shown in Figure 3 by using numerical studies.

Let $\Delta E\pi_S^{bb} = 0$ and $\Delta E\pi_E^{bb} = 0$. We compute $w_{A1} = 9.6309$ when in the point $A1$ and $w_{B1} = 10.5566$ when in the point $B1$. Figure 3 shows that $\Delta E\pi_S^{bb} > 0$ and $\Delta E\pi_E^{bb} > 0$ when in the region $w^{bb} \in (9.6309,\ 10.5566)$. The supplier and e-tailer both can earn more expected profits, leading to a Pareto improvement. Therefore, we have Observation 1 as follows.

Observation 1. When $w^{bb} \in (9.6309,\ 10.5566)$ and $b = [w^{bb} - 4.3477]/0.6523$, given buyback contracts (w^{bb}, b), supplier and e-tailer both can earn more expected profits than those under the wholesale price contract.

This result indicates that, comparing with wholesale price contract, buyback contract is more efficient for this fresh product supply chain. Given certain range of wholesale price, suppliers and e-tailers both can be better off under this buyback contract. Thus, we provide a requirement for this buyback contract to be implemented. Under this condition, suppliers have an incentive to offer and e-tailers would like to join in.

5.3. Revenue-Sharing Contracts. In this part, we try to investigate whether the revenue-sharing contract can coordinate the supply chain. Revenue-sharing contract is another common coordination contract which is applied massively in supply chain management. Under revenue-sharing contract (w^{rs}, φ), supplier first sets the wholesale price w^{rs} and e-tailer's share of revenue φ, and then e-tailer in response sets the price p, order quantity q, and fresh-keeping effort t to maximize expected profits. Based on whether the salvage value is shared or not, it can be divided into two types. When only sales revenue is shared, given e-tailer's revenue share φ_1, the expected profit of e-tailer is as follows:

$$\begin{aligned} &E\pi_E^{rs1}\left(p, q, t \mid w^{rs1}, \varphi_1\right) \\ &\quad = \varphi_1 p\left[1 - G\left(\frac{p}{\lambda\theta(t)}\right)\right]S(q) + s\left[q - S(q)\right] \\ &\qquad - w^{rs1}q - c(t). \end{aligned} \tag{15}$$

And when sales revenue and salvage values are both shared, given sales revenue and salvage values share φ_2, the expected profit of e-tailer is as follows:

$$\begin{aligned} &E\pi_E^{rs2}\left(p, q, t \mid w^{rs2}, \varphi_2\right) \\ &\quad = \varphi_2 p\left[1 - G\left(\frac{p}{\lambda\theta(t)}\right)\right]S(q) + \varphi_2 s\left[q - S(q)\right] \\ &\qquad - w^{rs2}q - c(t). \end{aligned} \tag{16}$$

Similar to Proposition 9, given revenue-sharing contracts (w^{rs1}, φ_1) and (w^{rs2}, φ_2), we first derive the joint optimal decisions, denoted as $\psi_5 = (p^{rs1*}, q^{rs1*}, t^{rs1*})$ and $\psi_6 = (p^{rs2*}, q^{rs2*}, t^{rs2*})$, respectively, and then let $\psi_5 = \psi_2$ and

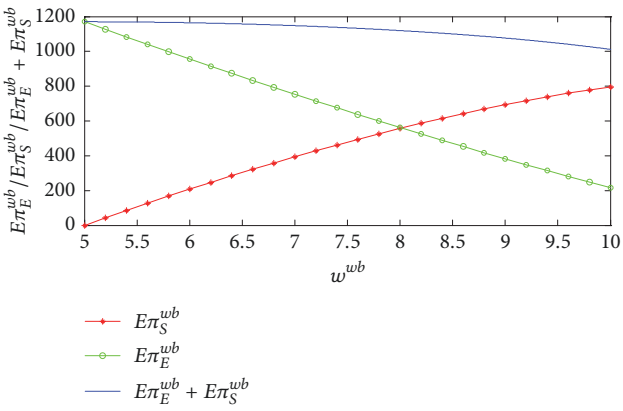

FIGURE 2: Expected profit change with w^{wb}.

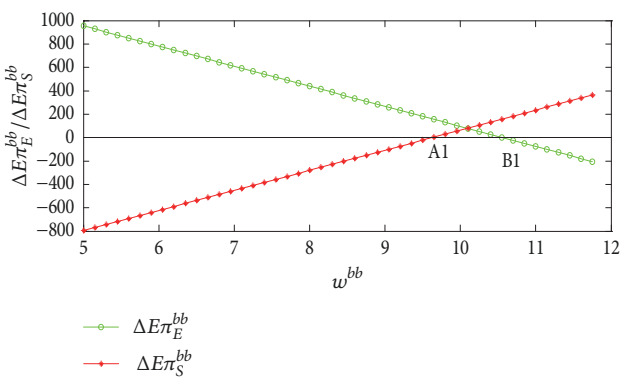

FIGURE 3: $\Delta E\pi_E{}^{bb}/\Delta E\pi_S{}^{bb}$ change with w^{bb}.

$\psi_6 = \psi_2$. However, only when $\varphi_1 = 1$, $\psi_5 = \psi_2$; and only when $\varphi_2 = 1$, $\psi_6 = \psi_2$. Thus, we have Proposition 11.

Proposition 11. *Whether salvage values are shared, revenue-sharing contracts (w^{rs}, φ) could not coordinate e-tailer when exerting a fresh-keeping effort.*

Proof. See Appendix. □

For a price-setting retailer, Cachon and Lariviere [47] illustrate that revenue-sharing contracts could achieve channel coordination when the sales revenue and salvage values are both shared. Proof of Proposition 11 shows that $\psi_5 = \psi_2$ ($\psi_6 = \psi_2$) only when $\varphi_1 = 1$ ($\varphi_2 = 1$). And when $\varphi_1 = 1$ ($\varphi_2 = 1$), $w^{rs1} = c$ ($w^{rs2} = c$) in our model formulation. This is a trivial case and the supplier can earn zero profit under the revenue-sharing contract. This means that when the e-tailer offers a full-refund return policy to consumers and sets the price, order quantity, and fresh-keeping effort jointly, the supplier cannot coordinate e-tailer by revenue-sharing contracts, even if the salvage value is shared. It is mainly because of lacking of cost-sharing between supplier and e-tailer. If without cost-sharing, the total cost of the fresh-keeping effort is internalized by e-tailer. Therefore, under pure revenue-sharing contracts, e-tailer has no incentive to choose the first best solution and instead chooses the suboptimal solution, in line with their self-interests, which leads to the failure of revenue-sharing contracts to achieve channel coordination.

5.4. Revenue- and cost-sharing contracts. In Section 5.3, Proposition 11 shows that a pure revenue-sharing contract could not coordinate the fresh product supply chain. Therefore, we examine a new contract in this part, called revenue- and cost-sharing contracts (w^{rc}, ϕ). Under this contract, supplier shares revenue and cost of the fresh-keeping effort with e-tailer. We assume e-tailer's share is ϕ and supplier's share is 1- ϕ. Similar to Section 5.3, the analysis can also be divided into two scenarios, depending on whether the salvage value is shared. If the salvage value is not shared and given revenue- and cost-sharing contract 1 (w^{rc1}, ϕ_1), the e-tailer's expected profit is as follows:

$$\begin{aligned} E\pi_E^{rc1}\left(p, q, t \mid w^{rc1}, \phi_1\right) &= \phi_1 p\left[1 - G\left(\frac{p}{\lambda\theta(t)}\right)\right] S(q) + s\left[q - S(q)\right] \\ &\quad - w^{rc1} q - \phi_1 c(t). \end{aligned} \tag{17}$$

If the salvage value is also shared and given revenue- and cost-sharing contract 2 (w^{rc2}, ϕ_2), the e-tailer's expected profit is as follows:

$$\begin{aligned} E\pi_E^{rc2}\left(p, q, t \mid w^{rc2}, \phi_2\right) &= \phi_2 p\left[1 - G\left(\frac{p}{\lambda\theta(t)}\right)\right] S(q) + \phi_2 s\left[q - S(q)\right] \\ &\quad - w^{rc2} q - \phi_2 c(t). \end{aligned} \tag{18}$$

Similar to Propositions 9 and 11, we first derive the joint optimal decisions under revenue- and cost-sharing contracts (w^{rc1}, ϕ_1) and (w^{rc2}, ϕ_2), respectively, denoted as $\psi_7 = (p^{rc1*}, q^{rc1*}, t^{rc1*})$ and $\psi_8 = (p^{rc2*}, q^{rc2*}, t^{rc2*})$, and then let $\psi_7 = \psi_2$ and $\psi_8 = \psi_2$. Thus, we have Proposition 12.

Proposition 12. *(i) When the salvage value is not shared, given*

$$w_{\min} = \frac{s\left[q^{cc*} - S\left(q^{cc*}\right)\right] / \left[(1/4)\lambda\theta\left(t^{cc*}\right) S\left(q^{cc*}\right) - c\left(t^{cc*}\right)\right] - sF\left(q^{cc*}\right) / \left[c - sF\left(q^{cc*}\right)\right]}{q^{cc*} / \left[(1/4)\lambda\theta\left(t^{cc*}\right) S\left(q^{cc*}\right) - c\left(t^{cc*}\right)\right] - 1 / \left[c - sF\left(q^{cc*}\right)\right]}, \tag{19}$$

and $\phi_1 = [w^{rc1} - sF(q^{cc*})]/[c - sF(q^{cc*})]$, for $w^{rc1} \in (w_{\min}, c)$, revenue- and cost-sharing contract 1 (w^{rc1}, ϕ_1) can coordinate supply chain and allocate the profit between e-tailer and supplier arbitrarily.

(ii) When the salvage value is also shared, given $\phi_2 = w^{rc2}/c$, *for* $w^{rc2} \in (0, c)$, *revenue- and cost-sharing contract 2* (w^{rc2}, ϕ_2) *can coordinate supply chain and divide profit between e-tailer and supplier arbitrarily.*

Proof. See Appendix. □

Proposition 12 demonstrates that when e-tailer exerts a fresh-keeping effort, it is necessary to share the cost of the fresh-keeping effort between the supply chain members to achieve channel coordination. This is consistent with Zhang et al. [52] that investigate the dyadic supply chain for deteriorating items and show that a revenue-sharing and cooperative investment contract can achieve coordination. Wu et al. [8] also demonstrate that revenue- and service-cost-sharing contracts can coordinate the logistics service level and achieve full channel coordination in a fresh product supply chain consisting of a distributor and a third-party logistics service provider. In industries, for collaborative new product development, Bhaskaran and Krishnan [53] address the fact that investment and innovation sharing complementary with revenue-sharing can help firms coordinate investments and improve products' quality and firms' profits. For example, two companies, i.e., Alpha Labs and Mega Pharmaceuticals, share the development investment and revenues both when developing a new innovative class of diabetes drugs [53]. Actually, revenue- and cost-sharing scheme has attracted more and more attention in the business world and is superior to pure revenue-sharing contracts when coordinating quality improvement efforts. However, our result is in sharp contrast to Yang and Chen [14] that address the fact that when the revenue-sharing and cost-sharing are both available, cost-sharing becomes dispensable. This contrast first may arise from the different model formulation between ours and Yang and Chen's [14]. Yang and Chen [14] formulate the model by deterministic demand and assume the retailer is Stackelberg leader. And our model is based on stochastic demand and assumes the supplier is Stackelberg leader. Second, the decision sequence is also different between ours and Yang and Chen's [14]. In Yang and Chen [14], the strategic interaction is modeled as a four-stage game; that is, the retailer moves first and offers the incentive scheme to the manufacturer; then, the manufacturer decides abatement level and wholesale price in the second and third stage, respectively; lastly, the retailer chooses his order quantity. And the strategic interaction in our model is much simpler; the supplier first offers an incentive scheme to e-tailer; then, the e-tailer chooses the price, order quantity, and fresh-keeping effort. Moreover, the channel efficiency when adding cost-sharing is also different. In Yang and Chen [14], cost-sharing is dispensable because revenue-sharing contract and revenue- and cost-sharing contract can achieve the same channel efficiency; however, the channel efficiency is only 3/4 under the two-incentive scheme. In our view, cost-sharing is necessary based on channel coordination and 100% channel efficiency. For these differences, the contract mechanism between ours and Yang and Chen's [14] also may be different.

Based on Proposition 12, taking the derivative of ϕ_1 (ϕ_2) with respect to λ, Corollary 13 can be obtained.

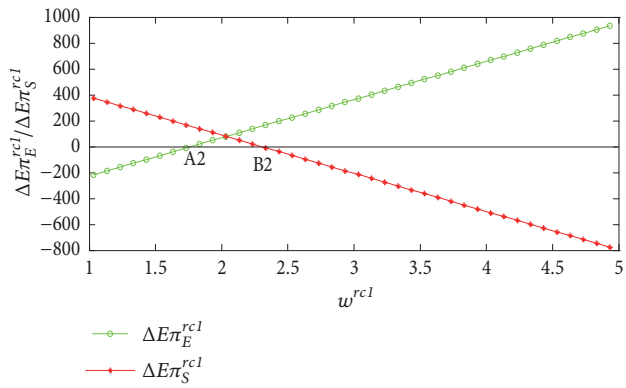

FIGURE 4: $\Delta E\pi_E{}^{rc1}/\Delta E\pi_S{}^{rc1}$ change with w^{rc1}.

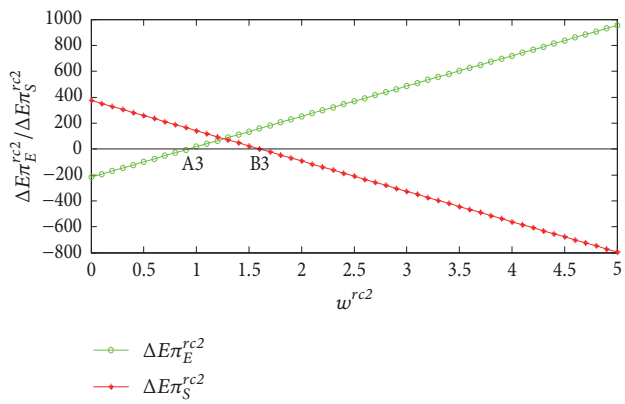

FIGURE 5: $\Delta E\pi_E{}^{rc2}/\Delta E\pi_S{}^{rc2}$ change with w^{rc2}.

Corollary 13. *Revenue- and cost-sharing ratio* ϕ_1 *is increasing in* λ, *i.e.,* $d\phi_1/d\lambda > 0$; *and* ϕ_2 *is independent of* λ.

Proof. See Appendix. □

Corollary 13 further shows that when the salvage value is not shared, e-tailer shares more revenue and cost when facing loss-averse consumers, compared with facing risk-neutral consumers. This means e-tailer's power will be increasing in λ in a coordinated setting. When the salvage value is also shared, e-tailer's share is independent of the loss-averse preference.

Similar to Section 5.2, we now examine whether the revenue- and cost-sharing contract can achieve Pareto improvement by using numerical studies. Letting $\Delta E\pi_E^{rc1} = E\pi_E^{rc1*} - E\pi_E^{wp*}$, $\Delta E\pi_S^{rc1} = E\pi_S^{rc1*} - E\pi_S^{wp*}$, $\Delta E\pi_E^{rc2} = E\pi_E^{rc2*} - E\pi_E^{wp*}$, and $\Delta E\pi_S^{rc2} = E\pi_S^{rc2*} - E\pi_S^{wp*}$, numerical results are depicted in Figures 4 and 5.

Let $\Delta E\pi_S^{rc1} = 0$ and $\Delta E\pi_E^{rc1} = 0$. We compute $w_{A2} = 1.7656$ when in the point $A2$ and $w_{B2} = 2.3054$ when in the point $B2$. Figure 4 shows that $\Delta E\pi_S^{rc1} > 0$ and $\Delta E\pi_E^{rc1} > 0$ when in the region $w^{rc1} \in (1.7656,\ 2.3054)$ supplier and e-tailer both can earn more expected profits, leading to Pareto improvement. Let $\Delta E\pi_S^{rc2} = 0$ and $\Delta E\pi_E^{rc2} = 0$. We compute $w_{A3} = 0.9245$ when in the point $A3$ and $w_{B3} = 1.6034$ when in the point $B3$. Figure 5 shows that $\Delta E\pi_S^{rc2} > 0$ and $\Delta E\pi_E^{rc2} > 0$

when in the region $w^{rc2} \in (0.9254,\ 1.6034)$ supplier and e-tailer both can earn more expected profits, leading to Pareto improvement. Therefore, we have Observations 2 and 3 as follows.

Observation 2. When $w^{rc1} \in (1.7656,\ 2.3054)$ and $\phi_1 = [w^{rc1} - 0.6523]/4.3477$, given revenue- and cost-sharing contract 1 (w^{rc1}, ϕ_1), supplier and e-tailer both can earn more expected profits than those under the wholesale price contract.

Observation 3. When $w^{rc2} \in (0.9245,\ 1.6034)$ and $\phi_2 = w^{rc2}/5$, given revenue- and cost-sharing contract 2 (w^{rc2}, ϕ_2), supplier and e-tailer both can earn more expected profits than those under the wholesale price contract.

Observations 2 and 3 both demonstrate that, comparing with wholesale price contract, revenue- and cost-sharing contract is more efficient for this fresh product supply chain. Given certain range of wholesale price, suppliers and e-tailers both can be better off under these revenue- and cost-sharing contracts. Thus, we provide a requirement for these revenue- and cost-sharing contracts to be implemented. Under this condition, suppliers have an incentive to offer and e-tailers would like to join in.

6. Conclusion

By considering consumer returns and loss-averse preference, we develop an analytical model to capture the price, inventory, and fresh-keeping effort decisions and coordination contracts for a fresh product supply chain. Our main results of this work can be summarized as follows:

(1) Given that the fresh product is high profit and demand distribution satisfies IFR, there exists a unique joint optimal solution of price, order quantity, and fresh-keeping effort. Based on the comparison, we find that profits are more with than without fresh-keeping effort. Therefore, the e-tailer has an incentive to engage in fresh-keeping effort.

(2) When the random variable y follows a uniform distribution, we further show that the return rate is independent of the fresh-keeping effort and consumers' loss aversion; but the optimal price and order quantity are both increasing in the fresh-keeping effort. Hence, exerting a fresh-keeping effort can increase the price and order quantity as well as expected net sales revenue.

(3) By making a sensitivity analysis, we also reveal that the optimal price, order quantity, fresh-keeping effort, and expected net sales revenue are all increasing in consumers' loss aversion, salvage value, and initial freshness but decreasing in purchasing cost. Hence, it is necessary to give higher price, order more, and exert more fresh-keeping effort for the company when facing loss-averse customers.

(4) In a decentralized setting, we first characterize the unique optimal joint decisions for e-tailer and then deliver the optimal wholesale price for supplier using a numerical study. A single wholesale price contract will induce e-tailer to set lower price and lower order quantity and also to exert fewer fresh-keeping efforts, which leads to a suboptimal supply chain.

(5) In a decentralized setting, we further examine the buyback and revenue-sharing contracts when e-tailer offers a full-refund return policy to the loss-averse consumer, demonstrating that the buyback contract still works, but the revenue-sharing contract fails to coordinate the supply chain. By designing new contractual mechanisms, we develop a new coordination contract: a revenue- and cost-sharing contract, which can coordinate the supply chain whether the salvage value is shared or not.

(6) Using numerical studies, we capture the Pareto improvement regions under the buyback and revenue- and cost-sharing contracts, under which the supplier and e-tailer both can earn more expected profits than those under the wholesale price contract.

Therefore, the insight from our model and analysis can be distilled into some rules for the managers in real business world. First, our research provides a principle for managers of when and how to exert a fresh-keeping effort. When the fresh product is in high profit scenarios, e-tailer can give higher price, order more, and earn more profit if exerting a fresh-keeping effort. Second, we ensure that the supplier can coordinate e-tailer's fresh-keeping effort and provide a guideline for managers on how to choose the supply chain contract among wholesale price, buyback, and revenue- and cost-sharing contracts. Finally, consumers also will be benefited by receiving fresher products, and more of them will purchase online because the expected sales are increasing in fresh-keeping effort.

Our research can be extended in several directions. First, the elegance of our results is based on a uniform distribution of the random variable y; therefore, in future work, it will be interesting to derive the closed-form solutions by alternative distributions. Second, similar to Su [15], we assume the stochastic demand is independent of the price; however, although incorporating a price-dependent demand function into our model is necessary, it will be difficult to derive analytical results. This will be our future endeavor. Third, our research is based on the full-refund return policy, though the partial-refund return policy may be more common, under which joint decision-making presents ample opportunities for future research.

Appendix

Proof of Proposition 3. (i) Given (2), take the first and second partial derivative of $E\pi_{EN}^{cc}(p \mid q)$ with respect to p as follows:

$$\frac{\partial E\pi_{EN}^{cc}(p \mid q)}{\partial p} = \left(1 - \frac{2p}{\lambda\theta_0}\right) S(q),$$
$$\frac{\partial^2 E\pi_{EN}^{cc}(p \mid q)}{\partial p^2} = -\frac{2S(q)}{\lambda\theta_0} < 0. \tag{A.1}$$

Therefore, $E\pi_{EN}^{cc}(p \mid q)$ is concave in p.

For $\partial E\pi_{EN}^{cc}(p \mid q)/\partial p|_{p=0} = S(q) > 0$ and $\partial E\pi_{EN}^{cc}(p \mid q)/\partial p|_{p=\lambda\theta_0} = -S(q) < 0$, hence, in the region $[0, \lambda\theta_0]$, there exists unique optimal retail price p_N^{cc*} maximizing $E\pi_{EN}^{cc}(p \mid q)$ when $\partial E\pi_{EN}^{cc}(p \mid q)/\partial p = 0$, which brings out (3).

(ii) For (3), we have the following:

$$E\pi_{EN}^{cc}(q) = \frac{\lambda\theta_0}{4}S(q) + s[q - S(q)] - cq. \tag{A.2}$$

Take the first and second partial derivative of $E\pi_{EN}^{cc}(q)$ with respect to q are as follows:

$$\begin{aligned}\frac{dE\pi_{EN}^{cc}(q)}{dq} &= \frac{\lambda\theta_0}{4}[1 - F(q)] + sF(q) - c,\\ \frac{d^2E\pi_{EN}^{cc}(q)}{dq^2} &= -\frac{\lambda\theta_0 f(q)}{4} + sf(q)\\ &= -\left[\frac{\lambda\theta_0}{4} - s\right]f(q).\end{aligned} \tag{A.3}$$

Given Assumption 1, $\lambda\theta_0/4 - s > 0$ follows and then $d^2E\pi_{EN}^{cc}(q)/dq^2 < 0$.

Therefore, $E\pi_{EN}^{cc}(q)$ is concave in q.

For $dE\pi_{EN}^{cc}(q)/dq|_{q=A} = \lambda\theta_0/4 - c > 0$ (Assumption 1) and $dE\pi_{EN}^{cc}(q)/dq|_{q=B} = s - c < 0$, hence, in the region $[A, B]$, there exists unique optimal quantity q_N^{cc*} maximizing $E\pi_{EN}^{cc}(q)$ when $dE\pi_{EN}^{cc}(q)/dq = 0$, which brings out (4). □

Proof of Proposition 4. (i) Given (1), take the first and second partial derivative of $E\pi_E^{cc}(p \mid q, t)$ with respect to p, as follows:

$$\begin{aligned}\frac{\partial E\pi_E^{cc}(p \mid q, t)}{p} &= \left[1 - \frac{2p}{\lambda\theta(t)}\right]S(q),\\ \frac{\partial^2 E\pi_E^{cc}(p \mid q, t)}{p^2} &= -\frac{2S(q)}{\lambda\theta(t)} < 0.\end{aligned} \tag{A.4}$$

Therefore, $E\pi_E^{cc}(p \mid q, t)$ is concave in p.

For $\partial E\pi_E^{cc}(p \mid q, t)/\partial p|_{p=0} = S(q) > 0$ and $\partial E\pi_E^{cc}(p \mid q, t)/\partial p|_{p=\lambda\theta(t)} = -S(q) < 0$, hence, in the region $[0, \lambda\theta(t)]$, there exists unique optimal retail price $p^{cc*}(t)$ maximizing $E\pi_E^{cc}(p \mid q, t)$ when $\partial E\pi_E^{cc}(p \mid q, t)/\partial p = 0$, which brings out (5).

(ii) For (5), $\theta(t) = \theta_0 + \alpha t^{1/\beta}$, and $c(t) = c_0 t^{\gamma}$, we have the following:

$$\begin{aligned}E\pi_E^{cc}(p^{cc*}(t), t \mid q) &= \frac{\lambda S(q)}{4}\left(\theta_0 + \alpha t^{1/\beta}\right)\\ &\quad + s[q - S(q)] - cq - c_0 t^{\gamma}.\end{aligned} \tag{A.5}$$

Take the first and second partial derivative of $E\pi_E^{cc}(p^{cc*}(t), t \mid q)$ with respect to t, as follows:

$$\begin{aligned}\frac{\partial E\pi_E^{cc}(p^{cc*}(t), t \mid q)}{\partial t} &= \frac{\lambda a S(q) t^{1/\beta - 1}}{4\beta} - c_0\gamma t^{\gamma - 1},\\ \frac{\partial^2 E\pi_E^{cc}(p^{cc*}(t), t \mid q)}{\partial t^2}&\\ = \frac{\lambda a(1-\beta)S(q)t^{1/\beta-2}}{4\beta^2} &- c_0\gamma(\gamma - 1)t^{\gamma-2} < 0.\end{aligned} \tag{A.6}$$

Therefore, $E\pi_E^{cc}(p^{cc*}(t), t \mid q)$ is concave in t.

For $\partial E\pi_E^{cc}(p^{cc*}(t), t \mid q)/\partial t|_{t=0} = +\infty$ and $\partial E\pi_E^{cc}(p^{cc*}(t), t \mid q)/\partial t|_{t=+\infty} = -\infty$, hence, in the region $[0, +\infty)$, there exists unique optimal fresh-keeping effort $t^{cc*}(q)$ maximizing $E\pi_E^{cc}(p^{cc*}(t), t \mid q)$ when $\partial E\pi_E^{cc}(p^{cc*}(t), t \mid q)/\partial t = 0$, which brings out (6).

(iii) For (6), $\theta(t) = \theta_0 + \alpha t^{1/\beta}$, and $c(t) = c_0 t^{\gamma}$, we have the following:

$$\begin{aligned}p^{cc*}(q) &= p^{cc*}(t^{cc*}(q))\\ &= \frac{\lambda}{2}\left[\theta_0 + \alpha\left(\frac{\lambda a S(q)}{4c_0\gamma\beta}\right)^{1/(\gamma\beta-1)}\right],\\ E\pi_E^{cc}(p^{cc*}(q), q, t^{cc*}(q))&\\ &= \frac{\lambda S(q)}{4}\left[\theta_0 + \alpha\left(\frac{\lambda a S(q)}{4c_0\gamma\beta}\right)^{1/(\gamma\beta-1)}\right]\\ &\quad + s[q - S(q)] - cq - c_0\left(\frac{\lambda a S(q)}{4c_0\gamma\beta}\right)^{\gamma\beta/(\gamma\beta-1)}.\end{aligned} \tag{A.7}$$

Take the first derivative of $E\pi_E^{cc}(p^{cc*}(q), q, t^{cc*}(q))$ with respect to q, as follows:

$$\begin{aligned}\frac{dE\pi_E^{cc}(p^{cc*}(q), q, t^{cc*}(q))}{dq}&\\ = \frac{(\lambda\theta_0 - 4s)(1 - F(q))}{4}&\\ + \frac{\lambda a(1 - F(q))}{4}\left(\frac{\lambda a S(q)}{4c_0\gamma\beta}\right)^{1/(\gamma\beta-1)} &- c + s.\end{aligned} \tag{A.8}$$

Let $H(q) = dE\pi_E^{cc}(p^{cc*}(q), q, t^{cc*}(q))/dq$ and $f'(q) = df(q)/dq$; we have the following:

$$\begin{aligned}\frac{dH(q)}{dq} &= -\frac{(\lambda\theta_0 - 4s)f(q)}{4}\\ &\quad - \frac{\lambda a f(q)}{4}\left(\frac{\lambda a S(q)}{4c_0\gamma\beta}\right)^{1/(\gamma\beta-1)}\\ &\quad + \frac{\lambda a(1 - F(q))^2}{4(\gamma\beta - 1)}\left(\frac{\lambda a}{4c_0\gamma\beta}\right)^{1/(\gamma\beta-1)}\\ &\quad \cdot S(q)^{(2-\gamma\beta)/(\gamma\beta-1)},\\ \frac{d^2H(q)}{dq^2} &= -\frac{(\lambda\theta_0 - 4s)f'(q)}{4}\\ &\quad - \frac{\lambda a f'(q)}{4}\left(\frac{\lambda a S(q)}{4c_0\gamma\beta}\right)^{1/(\gamma\beta-1)}\\ &\quad - \frac{3\lambda a[1 - F(q)]f(q)}{4(\gamma\beta - 1)}\left(\frac{\lambda a}{4c_0\gamma\beta}\right)^{1/(\gamma\beta-1)}\\ &\quad \cdot S(q)^{(2-\gamma\beta)/(\gamma\beta-1)}\end{aligned}$$

$$+\frac{(2-\gamma\beta)\lambda a[1-F(q)]^3}{4(\gamma\beta-1)^2}\left(\frac{\lambda a}{4c_0\gamma\beta}\right)^{1/(\gamma\beta-1)}$$

$$\cdot S(q)^{(3-2\gamma\beta)/(\gamma\beta-1)}=\frac{f'(q)}{f(q)}\left\{-\frac{(\lambda\theta_0-4s)f(q)}{4}\right.$$

$$-\frac{\lambda a f(q)}{4}\left(\frac{\lambda a S(q)}{4c_0\gamma\beta}\right)^{1/(\gamma\beta-1)}$$

$$+\frac{\lambda a[1-F(q)]^2}{4(\gamma\beta-1)}\left(\frac{\lambda a}{4c_0\gamma\beta}\right)^{1/(\gamma\beta-1)}$$

$$\left.\cdot S(q)^{(2-\gamma\beta)/(\gamma\beta-1)}\right\}$$

$$+\frac{\lambda a[1-F(q)]^3}{4(\gamma\beta-1)f(q)}\left(\frac{\lambda a}{4c_0\gamma\beta}\right)^{1/(\gamma\beta-1)}$$

$$\cdot S(q)^{(2-\gamma\beta)/(\gamma\beta-1)}\left\{-\frac{f'(q)[1-F(q)]+3f^2(q)}{[1-F(q)]^2}\right.$$

$$\left.+\frac{(2-\gamma\beta)f(q)}{(\gamma\beta-1)S(q)}\right\}=\frac{dH(q)}{dq}\frac{f'(q)}{f(q)}$$

$$+\frac{\lambda a[1-F(q)]^3}{4(\gamma\beta-1)f(q)}\left(\frac{\lambda a}{4c_0\gamma\beta}\right)^{1/(\gamma\beta-1)}$$

$$\cdot S(q)^{(2-\gamma\beta)/(\gamma\beta-1)}\left\{\frac{f'(q)[1-F(q)]+3f^2(q)}{-[1-F(q)]^2}\right.$$

$$\left.+\frac{(2-\gamma\beta)f(q)}{(\gamma\beta-1)S(q)}\right\} \tag{A.9}$$

Then, we have

$$\left.\frac{d^2H(q)}{dq^2}\right|_{dH(q)/dq=0}$$

$$=\frac{\lambda a[1-F(q)]^3}{4(\gamma\beta-1)f(q)}\left(\frac{\lambda a}{4c_0\gamma\beta}\right)^{1/(\gamma\beta-1)}$$

$$\cdot S(q)^{(2-\gamma\beta)/(\gamma\beta-1)} \tag{A.10}$$

$$\cdot\left\{-\frac{f'(q)[1-F(q)]+3f^2(q)}{[1-F(q)]^2}\right.$$

$$\left.+\frac{(2-\gamma\beta)f(q)}{(\gamma\beta-1)S(q)}\right\}$$

For $(\lambda a[1-F(q)]^3/4(\gamma\beta-1)f(q))(\lambda a/4c_0\gamma\beta)^{1/(\gamma\beta-1)}\cdot S(q)^{(2-\gamma\beta)/(\gamma\beta-1)}>0$ and $(2-\gamma\beta)f(q)/(\gamma\beta-1)S(q)<0$ given $\beta>1$ $\gamma\geq 2$, and $h'(q)+2h^2(q)=(f'(q)[1-F(q)]+3f^2(q))/[1-F(q)]^2>0$ based on Assumption 2, then, we have the following:

$$\left.\frac{d^2H(q)}{dq^2}\right|_{dH(q)/dq=0}<0. \tag{A.11}$$

Therefore, $H(q)$ is a unimodal function.

For $H(q)|_{q=A}=\lambda\theta_0/4+(\lambda a/4)(\lambda aS(A)/4c_0\gamma\beta)^{1/(\gamma\beta-1)}-c>0$ and $H(q)|_{q=B}=-c+s<0$, therefore, in the region $[A,B]$, $H(q)=0$ has only one root $q=q^{cc*}\in\{H(q)=0\}$.

For $H(q)>0$ when $A\leq q<q^{cc*}$ and $H(q)<0$ when $q^{cc*}<q\leq B$, therefore, in the region $[A,B]$, $E\pi_E^{cc}(p^{cc*}(q),q,t^{cc*}(q))$ is a unimodal function and reaches its maximum at the first-order condition $H(q)=0$, which is satisfied with (7). □

Proof of Proposition 5. For (7), $F(q^{cc*})=(\lambda\theta_0+\lambda a(\lambda aS(q^{cc*})/4\beta c_0\gamma)^{1/(\gamma\beta-1)}-4c)/(\lambda\theta_0+\lambda a(\lambda aS(q^{cc*})/4\beta c_0\gamma)^{1/(\gamma\beta-1)}-4s)$ follows; therefore, $F(q_N^{cc*})<F(q^{cc*})$ and $A<q_N^{cc*}<q^{cc*}<B$.

For (3), (5), and (6), we also can obtain $t^{cc*}>0$ and $0<p_N^{cc*}<p^{cc*}$.

Denote the solution space for $E\pi_E^{cc}(p,q,t)$ as Ψ; that is,

$$\Psi=\left\{p,q,t\mid p\geq 0,\ A\leq q\leq B,\ t\geq 0,\ p\left[1-\frac{p}{(\lambda\theta(t))}\right]-c>0\right\}. \tag{A.12}$$

Therefore, $\psi_1\in\Psi$ and $\psi_2\in\Psi$.

For (1) and (2), we have $E\pi_{EN}^{cc}(p_N^{cc*},q_N^{cc*})=E\pi_E^{cc}(p_N^{cc*},q_N^{cc*},t=0)$.

From the proof of Proposition 4, $(p^{cc*},q^{cc*},t^{cc*})$ is the unique solution which maximized $E\pi_E^{cc}(p,q,t)$; hence, $E\pi_E^{cc}(p_N^{cc*},q_N^{cc*},t=0)<E\pi_E^{cc}(p^{cc*},q^{cc*},t^{cc*})$ follows

$$E\pi_{EN}^{cc}(p_N^{cc*},q_N^{cc*})<E\pi_E^{cc}(p^{cc*},q^{cc*},t^{cc*}). \tag{A.13}$$

□

Proof of Corollary 7. For $t^{cc*}(q)=(\lambda aS(q)/4c_0\gamma\beta)^{\beta/(\gamma\beta-1)}$, letting $S(q^{cc*}(t))=(4c_0\gamma\beta/\lambda a)t^{(\gamma\beta-1)/\beta}$, then

$$\frac{dq^{cc*}(t)}{dt}=\frac{1}{1-F(q^{cc*}(t))}\frac{dS(q^{cc*}(t))}{dt}$$

$$=\frac{4c_0\gamma\beta(\gamma\beta-1)}{\lambda a\beta[1-F(q^{cc*}(t))]}t^{(\gamma\beta-\beta-1)/\beta}>0; \tag{A.14}$$

for $p^{cc*}(t)=\lambda\theta(t)/2$, then, $dp^{cc*}(t)/dt=(\lambda/2)(d\theta(t)/dt)>0$. □

Proof of Corollary 8. (i-1) Let $\Theta=[(\lambda\theta_0-4s)/4+(\lambda a/4)(\lambda aS(q^{cc*})/4\beta c_0\gamma)^{1/(\gamma\beta-1)}][1-F(q^{cc*})]-c+s$; then

$$\frac{dq^{cc*}}{d\lambda} = -\frac{\partial\Theta/\partial\lambda}{\partial\Theta/\partial q^{cc*}} = -\frac{\left[\theta_0 + (a\gamma\beta/(\gamma\beta-1))(\lambda a S(q^{cc*})/4c_0\gamma\beta)^{1/(\gamma\beta-1)}\right]([1-F(q^{cc*})]/4)}{(d^2E\pi(p^{cc*}(q), t^{cc*}(q), q)/dq^2)|_{q=q^{cc*}}}. \tag{A.15}$$

For $E\pi_E^{cc}(p^{cc*}(q), q, t^{cc*}(q))$ is a unimodal function and $q = q^{cc*}$ is the unique optimal decision as addressed in the proof of Proposition 4, we have the following:

$$\left.\frac{d^2E\pi_E^{cc}(p^{cc*}(q), q, t^{cc*}(q))}{dq^2}\right|_{q=q^{cc*}} < 0. \tag{A.16}$$

Then, we have $dq^{cc*}/d\lambda > 0$.

(i-2) For $t^{cc*} = (\lambda a S(q^{cc*})/4c_0\gamma\beta)^{\beta/(\gamma\beta-1)}$, then, $\partial t^{cc*}/\partial q^{cc*} = (\beta[1-F(q^{cc*})]/(\gamma\beta-1))(\lambda a/4c_0\gamma\beta)^{\beta/(\gamma\beta-1)} \cdot S(q^{cc*})^{(\beta-\gamma\beta+1)/(\gamma\beta-1)} > 0$; we have the following:

$$\begin{aligned}\frac{dt^{cc*}}{d\lambda} &= \frac{\partial t^{cc*}}{\partial\lambda} + \frac{\partial t^{cc*}}{\partial q^{cc*}}\frac{dq^{cc*}}{d\lambda} \\ &= \frac{\beta}{\gamma\beta-1}\lambda^{(\beta-\gamma\beta+1)/(\gamma\beta-1)}\left(\frac{aS(q^{cc*})}{4c_0\gamma\beta}\right)^{\beta/(\gamma\beta-1)} \\ &\quad + \frac{\partial t^{cc*}(q^{cc*})}{\partial q^{cc*}}\frac{dq^{cc*}}{d\lambda} > 0.\end{aligned} \tag{A.17}$$

(i-3) For $p^{cc*} = \lambda\theta(t^{cc*})/2$, then,

$$\begin{aligned}\frac{dp^{cc*}}{d\lambda} &= \frac{\lambda}{2}\frac{d\theta(t^{cc*})}{d\lambda} + \frac{\theta(t^{cc*})}{2} \\ &= \frac{\lambda}{2}\frac{d\theta(t^{cc*})}{dt^{cc*}}\frac{dt^{cc*}}{d\lambda} + \frac{\theta(t^{cc*})}{2} > 0.\end{aligned} \tag{A.18}$$

(i-4) For $\Pi(t^{cc*}) = (1-R)p^{cc*}(t^{cc*})S(q^{cc*}(t^{cc*}))$, then,

$$\begin{aligned}\frac{d\Pi(t^{cc*})}{d\lambda} &= (1-R) \\ &\cdot\left[S(q^{cc*}(t^{cc*}))\frac{dp^{cc*}(t^{cc*})}{dt^{cc*}}\frac{dt^{cc*}}{d\lambda} + p^{cc*}(t)\right. \\ &\cdot\left.[1-F(q^{cc*}(t^{cc*}))]\frac{dq^{cc*}(t^{cc*})}{dt^{cc*}}\frac{dt^{cc*}}{d\lambda}\right] > 0.\end{aligned} \tag{A.19}$$

(ii-1) Similar to the proof of (i-1), we have

$$\begin{aligned}\frac{dq^{cc*}}{ds} &= -\frac{\partial\Theta/\partial s}{\partial\Theta/\partial q^{cc*}} \\ &= -\frac{F(q^{cc*})}{(d^2E\pi(p^{cc*}(q), t^{cc*}(q), q)/dq^2)|_{q=q^{cc*}}} \\ &> 0.\end{aligned} \tag{A.20}$$

(ii-2) For $t^{cc*} = (\lambda a S(q^{cc*})/4c_0\gamma\beta)^{\beta/(\gamma\beta-1)}$ and $\partial t^{cc*}/\partial q^{cc*} = (\beta[1-F(q^{cc*})]/(\gamma\beta-1))(\lambda a/4c_0\gamma\beta)^{\beta/(\gamma\beta-1)} \cdot S(q^{cc*})^{(\beta-\gamma\beta+1)/(\gamma\beta-1)} > 0$, we have the following:

$$\frac{dt^{cc*}}{ds} = \frac{\partial t^{cc*}}{\partial q^{cc*}}\frac{dq^{cc*}}{ds} > 0. \tag{A.21}$$

(ii-3) For $p^{cc*} = \lambda\theta(t^{cc*})/2$, then,

$$\frac{dp^{cc*}}{ds} = \frac{\lambda}{2}\frac{d\theta(t^{cc*})}{ds} = \frac{\lambda}{2}\frac{d\theta(t^{cc*})}{dt^{cc*}}\frac{dt^{cc*}}{ds} > 0. \tag{A.22}$$

(ii-4) For $\Pi(t^{cc*}) = (1-R)p^{cc*}(t^{cc*})S(q^{cc*}(t^{cc*}))$, then,

$$\begin{aligned}\frac{d\Pi(t^{cc*})}{ds} &= (1-R) \\ &\cdot\left[S(q^{cc*}(t^{cc*}))\frac{dp^{cc*}(t^{cc*})}{dt^{cc*}}\frac{dt^{cc*}}{ds} + p^{cc*}(t^{cc*})\right. \\ &\cdot\left.[1-F(q^{cc*}(t^{cc*}))]\frac{dq^{cc*}(t^{cc*})}{dt^{cc*}}\frac{dt^{cc*}}{ds}\right] > 0.\end{aligned} \tag{A.23}$$

(iii-1) Similar to the proof of (i-1), we have

$$\begin{aligned}\frac{dq^{cc*}}{d\theta_0} &= -\frac{\partial\Theta/\partial\theta_0}{\partial\Theta/\partial q^{cc*}} \\ &= -\frac{\lambda[1-F(q^{cc*})]/4}{(d^2E\pi(p^{cc*}(q), t^{cc*}(q), q)/dq^2)|_{q=q^{cc*}}} \\ &> 0.\end{aligned} \tag{A.24}$$

(iii-2) For $t^{cc*} = (\lambda a S(q^{cc*})/4c_0\gamma\beta)^{\beta/(\gamma\beta-1)}$ and $\partial t^{cc*}/\partial q^{cc*} = (\beta[1-F(q^{cc*})]/(\gamma\beta-1))(\lambda a/4c_0\gamma\beta)^{\beta/(\gamma\beta-1)} \cdot S(q^{cc*})^{(\beta-\gamma\beta+1)/(\gamma\beta-1)} > 0$, we have the following:

$$\frac{dt^{cc*}}{d\theta_0} = \frac{\partial t^{cc*}}{\partial q^{cc*}}\frac{dq^{cc*}}{d\theta_0} > 0. \tag{A.25}$$

(iii-3) For $p^{cc*} = \lambda\theta(t^{cc*})/2$, then,

$$\frac{dp^{cc*}}{d\theta_0} = \frac{\lambda}{2}\frac{d\theta(t^{cc*})}{d\theta_0} = \frac{\lambda}{2}\frac{d\theta(t^{cc*})}{dt^{cc*}}\frac{dt^{cc*}}{d\theta_0} > 0. \tag{A.26}$$

(iii-4) For $\Pi(t^{cc*}) = (1-R)p^{cc*}(t^{cc*})S(q^{cc*}(t^{cc*}))$, then,

$$\begin{aligned}\frac{d\Pi(t^{cc*})}{d\theta_0} &= (1-R) \\ &\cdot\left[S(q^{cc*}(t^{cc*}))\frac{dp^{cc*}(t^{cc*})}{dt^{cc*}}\frac{dt^{cc*}}{d\theta_0} + p^{cc*}(t^{cc*})\right. \\ &\cdot\left.[1-F(q^{cc*}(t^{cc*}))]\frac{dq^{cc*}(t^{cc*})}{dt^{cc*}}\frac{dt^{cc*}}{d\theta_0}\right] > 0.\end{aligned} \tag{A.27}$$

(iv-1) Similar to the proof of (i-1), we have

$$\begin{aligned}\frac{dq^{cc*}}{dc} &= -\frac{\partial\Theta/\partial c}{\partial\Theta/\partial q^{cc*}} \\ &= -\frac{-1}{\left(d^2E\pi\left(p^{cc*}(q), t^{cc*}(q), q\right)/dq^2\right)\big|_{q=q^{cc*}}} \\ &< 0.\end{aligned} \tag{A.28}$$

(iv-2) For $t^{cc*} = (\lambda a S(q^{cc*})/4c_0\gamma\beta)^{\beta/(\gamma\beta-1)}$ and $\partial t^{cc*}/\partial q^{cc*} = (\beta[1 - F(q^{cc*})]/(\gamma\beta - 1))(\lambda a/4c_0\gamma\beta)^{\beta/(\gamma\beta-1)} \cdot S(q^{cc*})^{(\beta-\gamma\beta+1)/(\gamma\beta-1)} > 0$, we have the following:

$$\frac{dt^{cc*}}{dc} = \frac{\partial t^{cc*}}{\partial q^{cc*}}\frac{dq^{cc*}}{dc} < 0. \tag{A.29}$$

(iv-3) For $p^{cc*} = \lambda\theta(t^{cc*})/2$, we have the following:

$$\frac{dp^{cc*}}{dc} = \frac{\lambda}{2}\frac{d\theta\left(t^{cc*}\right)}{dc} = \frac{\lambda}{2}\frac{d\theta\left(t^{cc*}\right)}{dt^{cc*}}\frac{dt^{cc*}}{dc} < 0. \tag{A.30}$$

(iv-4) For $\Pi(t^{cc*}) = (1 - R)p^{cc*}(t^{cc*})S(q^{cc*}(t^{cc*}))$, then,

$$\begin{aligned}\frac{d\Pi\left(t^{cc*}\right)}{dc} &= (1-R) \\ &\cdot\left[S\left(q^{cc*}\left(t^{cc*}\right)\right)\frac{dp^{cc*}\left(t^{cc*}\right)}{dt^{cc*}}\frac{dt^{cc*}}{dc} + p^{cc*}\left(t^{cc*}\right)\right. \\ &\left.\cdot\left[1 - F\left(q^{cc*}\left(t^{cc*}\right)\right)\right]\frac{dq^{cc*}\left(t^{cc*}\right)}{dt^{cc*}}\frac{dt^{cc*}}{dc}\right] < 0.\end{aligned} \tag{A.31}$$

□

Proof of Proposition 9. Similar to the proof of Proposition 4, given buyback contracts (w^{bb}, b) and (13), the e-tailer's optimal order quantity q^{bb*} is satisfied with

$$\begin{aligned}&\left[\frac{\lambda\theta_0 - 4b}{4} + \frac{\lambda a}{4}\left(\frac{\lambda a S\left(q^{bb*}\right)}{4\beta c_0\gamma}\right)^{1/(\gamma\beta-1)}\right] \\ &\cdot\left[1 - F\left(q^{bb*}\right)\right] - \left(w^{bb} - b\right) = 0,\end{aligned} \tag{A.32}$$

and the optimal fresh-keeping effort and price are $t^{bb*} = (\lambda a S(q^{bb*})/4c_0\gamma\beta)^{\beta/(\gamma\beta-1)}$ and $p^{bb*} = \lambda\theta(t^{bb*})/2$, respectively.

For (7) and (A.32), we have the following:

$$\begin{aligned}&\left[\frac{\lambda\theta_0}{4} + \frac{\lambda a}{4}\left(\frac{\lambda a S\left(q^{bb*}\right)}{4\beta c_0\gamma}\right)^{1/(\gamma\beta-1)}\right]\left[1 - F\left(q^{bb*}\right)\right] \\ &\quad = b\left[1 - F\left(q^{bb*}\right)\right] + \left(w^{bb} - b\right), \\ &\left[\frac{\lambda\theta_0}{4} + \frac{\lambda a}{4}\left(\frac{\lambda a S\left(q^{cc*}\right)}{4\beta c_0\gamma}\right)^{1/(\gamma\beta-1)}\right]\left[1 - F\left(q^{cc*}\right)\right] \\ &\quad = s\left[1 - F\left(q^{cc*}\right)\right] + c - s.\end{aligned} \tag{A.33}$$

Let $q^{bb*} = q^{cc*}$; then, $b[1 - F(q^{bb*})] + w^{bb} - b = s[1 - F(q^{cc*})] + c - s$; we have the following:

$$b = \frac{w^{bb} - c + sF\left(q^{cc*}\right)}{F\left(q^{cc*}\right)}. \tag{A.34}$$

Therefore, when $b = (w^{bb} - c + sF(q^{cc*}))/F(q^{cc*})$, we have the following:

$$\begin{aligned}q^{bb*} &= q^{cc*}, \\ t^{bb*} &= \left(\frac{\lambda a S\left(q^{bb*}\right)}{4c_0\gamma\beta}\right)^{\beta/(\gamma\beta-1)} = t^{cc*} \\ &= \left(\frac{\lambda a S\left(q^{cc*}\right)}{4c_0\gamma\beta}\right)^{\beta/(\gamma\beta-1)}, \\ p^{bb*} &= \frac{\lambda\left(t^{bb*}\right)}{2} = p^{cc*} = \frac{\lambda\left(t^{cc*}\right)}{2}.\end{aligned} \tag{A.35}$$

Therefore, buyback contracts $(w^{bb}, (w^{bb} - c + sF(q^{cc*}))/F(q^{cc*}))$ can induce the e-tailer to choose the first best solution.

Under the buyback contract $(w^{bb}, (w^{bb} - c + sF(q^{cc*}))/F(q^{cc*}))$, the e-tailer's expected profit is

$$\begin{aligned}E\pi_E^{bb*} &= E\pi_E^{bb}\left(p^{cc*}, q^{cc*}, t^{cc*}, w^{bb}, b\right) \\ &= \frac{\lambda\theta\left(t^{cc*}\right)}{4}S\left(q^{cc*}\right) \\ &\quad + \frac{w^{bb} - c + sF\left(q^{cc*}\right)}{F\left(q^{cc*}\right)}\left[q - S\left(q^{cc*}\right)\right] \\ &\quad - w^{bb}q^{cc*} - c\left(t^{cc*}\right),\end{aligned} \tag{A.36}$$

and the supplier's expected profit is

$$\begin{aligned}E\pi_S^{bb*} &= E\pi_S^{bb}\left(q^{cc*}, w^{bb}, b\right) \\ &= w^{bb}q^{cc*} - (b - s)\left[q^{cc*} - S\left(q^{cc*}\right)\right] - cq^{cc*} \\ &= E\pi_E^{cc*} - E\pi_E^{bb*}.\end{aligned} \tag{A.37}$$

For $dE\pi_E^{bb*}/dw^{bb} = (q^{cc*} - S(q^{cc*}) - q^{cc*}F(q^{cc*}))/F(q^{cc*})$ let $\Theta(q) = q - S(q) - qF(q)$ when $q \in [A, B]$.

For $d\Theta(q)/dq = -qf(q) < 0$ and $\Theta(A) = 0$, then, $\Theta(q) < 0$ in the region $q \in (A, B]$; we have the following:

$$\frac{dE\pi_E^{bb*}}{dw^{bb}} = \frac{\Theta\left(q^{cc*}\right)}{F\left(q^{cc*}\right)} < 0. \tag{A.38}$$

Hence, $E\pi_E^{bb*}$ is decreasing in w^{bb} monotonously.

Let

$$w_{\max} = \frac{\left[sF\left(q^{cc*}\right) - c\right]/F\left(q^{cc*}\right) - \left[c\left(t^{cc*}\right) - (1/4)\lambda\theta\left(t^{cc*}\right)S\left(q^{cc*}\right)\right]/\left[q^{cc*} - S\left(q^{cc*}\right)\right]}{q^{cc*}/\left[q^{cc*} - S\left(q^{cc*}\right)\right] - 1/F\left(q^{cc*}\right)}, \tag{A.39}$$

for $E\pi_E^{bb*}|_{w^{bb}=c} = E\pi_E^{cc*}$ and $E\pi_E^{bb*}|_{w^{bb}=w_{\max}} = 0$; therefore, in the region $w^{bb} \in (c, w_{\max})$, $E\pi_E^{bb*}$ is decreasing in w^{bb} monotonously and $0 < E\pi_E^{bb*} < E\pi_E^{cc*}$.

For $E\pi_S^{bb*} = E\pi_E^{cc*} - E\pi_E^{bb*}$, therefore, $E\pi_S^{bb*}$ is increasing in w^{bb} monotonously and $0 < E\pi_S^{bb*} < E\pi_E^{cc*}$ in the region $w^{bb} \in (c, w_{\max})$. And we also can obtain $E\pi_S^{bb*}|_{w^{bb}=c} = 0$ and $E\pi_S^{bb*}|_{w^{bb}=w_{\max}} = E\pi_E^{cc*}$.

Therefore, in the region $w^{bb} \in (c, w_{\max})$, given $b = (w^{bb} - c + sF(q^{cc*}))/F(q^{cc*})$, buyback contract $(w^{bb}, (w^{bb} - c + sF(q^{cc*}))/F(q^{cc*}))$ can coordinate the supply chain and arbitrarily allocate the profit between e-tailer and supplier. □

Proof of Corollary 10. For $b = (w^{bb} - c + sF(q^{cc*}))/F(q^{cc*})$, we have the following:

$$\frac{db}{d\lambda} = -\left(w^{bb} - c\right)F\left(q^{cc*}\right)^{-2} f\left(q^{cc*}\right)\frac{dq^{cc*}}{d\lambda} < 0. \tag{A.40}$$

□

Proof of Proposition 11. When salvage value is not shared, similar to the proof of Proposition 4, we obtain the optimal fresh-keeping effort, price, and order quantity given (w^{rs1}, φ_1) based on (15); that is,

$$\begin{gathered}\left[\frac{\varphi_1\lambda\theta_0 - 4s}{4} + \frac{\varphi_1\lambda a}{4}\left(\frac{\varphi_1\lambda a S\left(q^{rs1*}\right)}{4\beta c_0\gamma}\right)^{1/(\gamma\beta-1)}\right] \\ \cdot\left[1 - F\left(q^{rs1*}\right)\right] - \left(w^{rs1} - s\right) = 0, \\ t^{rs1*} = \left(\frac{\varphi_1\lambda a S\left(q^{rs1*}\right)}{4c_0\gamma\beta}\right)^{\beta/(\gamma\beta-1)} \quad \text{and} \\ p^{rs1*} = \frac{\lambda\theta\left(t^{rs1*}\right)}{2}.\end{gathered} \tag{A.41}$$

Let $q^{rs1*} = q^{cc*}$; then only when $\varphi_1 = 1$, $t^{rs1*} = t^{cc*}$ follows, and $p^{rs1*} = p^{cc*}$. When $\varphi_1 = 1$, $w^{rs1} = c$ follows directly. Therefore, revenue-sharing contract (w^{rs1}, φ_1) cannot achieve channel coordination.

When salvage value is also shared, we can obtain the same result using similar method. The proof is simple; hence, we omit it. □

Proof of Proposition 12. (i) Salvage value is not shared.

Similar to the proof of Proposition 4, given (w^{rc1}, ϕ_1), we can obtain the optimal order quantity, fresh-keeping effort, and price based on (17); that is,

$$\begin{gathered}\left[\frac{\phi_1\lambda\theta_0 - 4s}{4} + \frac{\phi_1\lambda a}{4}\left(\frac{\lambda a S\left(q^{rc1*}\right)}{4\beta c_0\gamma}\right)^{1/(\gamma\beta-1)}\right] \\ \cdot\left[1 - F\left(q^{rc1*}\right)\right] - \left(w^{rc1} - s\right) = 0, \\ t^{rc1*} = \left(\frac{\lambda a S\left(q^{rc1*}\right)}{4c_0\gamma\beta}\right)^{\beta/(\gamma\beta-1)}, \\ p^{rc1*} = \frac{\lambda\theta\left(t^{rc1*}\right)}{2}.\end{gathered} \tag{A.42, A.43}$$

For (7) and (A.42), we have the following:

$$\begin{gathered}\left[\frac{\lambda\theta_0}{4} + \frac{\lambda a}{4}\left(\frac{\lambda a S\left(q^{rc1*}\right)}{4\beta c_0\gamma}\right)^{1/(\gamma\beta-1)}\right] \\ \cdot\left[1 - F\left(q^{rc1*}\right)\right] = \frac{w^{rc1} - s + s\left[1 - F\left(q^{rc1*}\right)\right]}{\phi_1}, \\ \left[\frac{\lambda\theta_0}{4} + \frac{\lambda a}{4}\left(\frac{\lambda a S\left(q^{cc*}\right)}{4\beta c_0\gamma}\right)^{1/(\gamma\beta-1)}\right]\left[1 - F\left(q^{cc*}\right)\right] \\ = c - s + s\left[1 - F\left(q^{cc*}\right)\right].\end{gathered} \tag{A.44}$$

Let $q^{rc1*} = q^{cc*}$; then $(w^{rc1} - s + s[1 - F(q^{rc1*})])/\phi_1 = s[1 - F(q^{cc*})] + c - s$, and we have the following:

$$\phi_1 = \frac{w^{rc1} - sF\left(q^{cc*}\right)}{c - sF\left(q^{cc*}\right)}. \tag{A.45}$$

Therefore, when $\phi_1 = (w^{rc1} - sF(q^{cc*}))/(c - sF(q^{cc*}))$, we have the following:

$$\begin{gathered}q^{rc1*} = q^{cc*}, \\ t^{rc1*} = \left(\frac{\lambda a S\left(q^{rc1*}\right)}{4\beta c_0\gamma}\right)^{\beta/(\gamma\beta-1)} = t^{cc*} \\ = \left(\frac{\lambda a S\left(q^{cc*}\right)}{4\beta c_0\gamma}\right)^{\beta/(\gamma\beta-1)}, \\ p^{rc1*} = \frac{\lambda\theta\left(t^{rc1*}\right)}{2} = p^{cc*} = \frac{\lambda\theta\left(t^{cc*}\right)}{2}.\end{gathered} \tag{A.46}$$

Therefore, revenue- and cost-sharing contracts $(w^{rc1}, (w^{rc1} - sF(q^{cc*}))/(c - sF(q^{cc*})))$ can induce the e-tailer to choose the first best solution.

Under the revenue- and cost-sharing contract $(w^{rc1}, (w^{rc1} - sF(q^{cc*}))/(c - sF(q^{cc*})))$, the e-tailer's expected profit is

$$\begin{aligned} E\pi_E^{rc1*} &= E\pi_E^{rc1}\left(p^{cc*}, q^{cc*}, t^{cc*}, w^{rc1}, \phi_1\right) \\ &= \frac{w^{rc1} - sF\left(q^{cc*}\right)}{c - sF\left(q^{cc*}\right)}\left[\frac{\lambda\theta}{4}S\left(q^{cc*}\right) - c\left(t^{cc*}\right)\right] \\ &\quad + s\left[q^{cc*} - S\left(q^{cc*}\right)\right] - w^{rc1}q^{cc*}, \end{aligned} \tag{A.47}$$

and the supplier's expected profit is

$$\begin{aligned} E\pi_S^{rc1*} &= E\pi_S^{rc1}\left(q^{cc*}, t^{cc*}, w^{rc1}, \phi_1\right) \\ &= \frac{c - w^{rc1}}{c - sF\left(q^{cc*}\right)}\left[\frac{\lambda\theta}{4}S\left(q^{cc*}\right) - c\left(t^{cc*}\right)\right] \\ &\quad + \left(w^{rc1} - c\right)q = E\pi_E^{cc*} - E\pi_E^{rc1*}. \end{aligned} \tag{A.48}$$

For $0 < \phi_1 = (w^{rc1} - sF(q^{cc*}))/(c - sF(q^{cc*})) \le 1$, $sF(q^{cc*}) < w^{rc1} \le c$ follows.

For $dE\pi_E^{rc1*}/dw^{rc1} = \lambda\theta(t^{cc*})S(q^{cc*})/4[c - sF(q^{cc*})] - q^{cc*} - c(t^{cc*})/(c - sF(q^{cc*}))$ is independent of w^{rc1} and $E\pi_E^{rc1*}|_{w^{rc1}=c} = (\lambda\theta(t^{cc*})/4)S(q^{cc*}) + s[q^{cc*} - S(q^{cc*})] - cq^{cc*} - c(t^{cc*}) = E\pi_E^{cc*}$, hence, $E\pi_E^{rc1*}$ is monotone increasing in w^{rc1} in the region $w^{rc1} \in (sF(q^{cc*}), c]$.

When $w^{rc1} = sF(q^{cc*})$, then $E\pi_E^{rc1*} = s[q^{cc*} - S(q^{cc*})] - sF(q^{cc*})q^{cc*}$.

Let $\Omega(q) = s[q - S(q)] - sF(q)q$; then $d\Omega(q)/dq = -sqf(q) < 0$ and $\Omega(q)|_{q=A} = 0$; therefore, $\Omega(q) < 0$ in the region $(A, B]$, and $E\pi_E^{rc1*}|_{w^{rc1}=sF(q_C^*)} < 0$ follows.

Let

$$w_{\min} = \frac{s\left[q^{cc*} - S\left(q^{cc*}\right)\right] / \left[(1/4)\lambda\theta\left(t^{cc*}\right)S\left(q^{cc*}\right) - c\left(t^{cc*}\right)\right] - sF\left(q^{cc*}\right) / \left[c - sF\left(q^{cc*}\right)\right]}{q^{cc*} / \left[(1/4)\lambda\theta\left(t^{cc*}\right)S\left(q^{cc*}\right) - c\left(t^{cc*}\right)\right] - 1 / \left[c - sF\left(q^{cc*}\right)\right]}, \tag{A.49}$$

and we have the following:

$$E\pi_E^{rc1*}\Big|_{w^{rc1}=w_{\min}} = 0. \tag{A.50}$$

Therefore, $E\pi_E^{rc1*}$ is monotone increasing in w^{rc1} and $0 < E\pi_E^{rc1*} < E\pi_E^{cc*}$ in the region $w^{rc1} \in (sF(q^{cc*}), c)$.

For $E\pi_S^{rc1*} = E\pi_E^{cc*} - E\pi_E^{rc1*}$, therefore, $E\pi_S^{rc1*}$ is monotone decreasing in w^{rc1} and $0 < E\pi_S^{rc1*} < E\pi_E^{cc*}$ in the region $w^{rc1} \in (sF(q^{cc*}), c)$. And we also can obtain $E\pi_S^{rc1*}|_{w^{rc1}=w_{\min}} = E\pi_E^{cc*}$ and $E\pi_S^{rc1*}|_{w^{rc1}=c} = 0$.

Therefore, in the region $w_{rc1} \in (w_{\min}, c)$, given $\phi_1 = (w^{rc1} - sF(q^{cc*}))/(c - sF(q^{cc*}))$, the revenue- and cost-sharing contract (w^{rc1}, φ_1) can coordinate the supply chain and arbitrarily allocate the profit between e-tailer and supplier.

(ii) Salvage value is also shared.

Similar to the proof of Proposition 4, given (w^{rc2}, ϕ_2), we can obtain the optimal order quantity, fresh-keeping effort, and price based on (18), noted as $\psi_8 = (p^{rc2*}, q^{rc2*}, t^{rc2*})$.

Let $\phi_2 = w^{rc2}/c$ and $\psi_8 = \psi_2$, based on (18); we have the following:

$$\begin{aligned} E\pi_E^{rc2*} &= E\pi_E^{rc2}\left(p^{cc*}, q^{cc*}, t^{cc*}, w^{rc2}, \phi_2\right) \\ &= \phi_2\left\{\frac{\lambda\theta\left(t^{cc*}\right)}{4}S\left(q^{cc*}\right) + s\left[q^{cc*} - S\left(q^{cc*}\right)\right]\right. \\ &\quad \left. - cq^{cc*} - c\left(t^{cc*}\right)\right\} = \phi_2 E\pi_E^{cc*}, \end{aligned} \tag{A.51}$$

and, then, the supplier's expected profit is

$$\begin{aligned} E\pi_S^{rc2*} &= E\pi_S^{rc2}\left(q^{cc*}, t^{cc*}, w^{rc2}, \phi_2\right) = \left(1 - \phi_2\right) \\ &\quad \cdot \left\{\frac{\lambda\theta\left(t^{cc*}\right)}{4}S\left(q^{cc*}\right) + s\left[q^{cc*} - S\left(q^{cc*}\right)\right]\right. \\ &\quad \left. - c\left(t^{cc*}\right)\right\} + w^{rc2}q^{cc*} - cq^{cc*} = \left(1 - \phi_2\right) \\ &\quad \cdot E\pi_E^{cc}\left(p, q, t\right). \end{aligned} \tag{A.52}$$

When, in the region $w^{rc2} \in (0, c)$, $\phi_2 \in (0, 1)$ follows, therefore, the revenue- and cost-sharing contract 2 (w^{rc2}, ϕ_2) can coordinate the supply chain and allocate the profit between e-tailer and supplier arbitrarily. □

Proof of Corollary 13. For $\phi_1 = (w^{rc1} - sF(q^{cc*}))/(c - sF(q^{cc*}))$, we have the following:

$$\begin{aligned} \frac{d\phi_1}{d\lambda} &= \frac{-sf\left(q^{cc*}\right)\left(dq^{cc*}/\lambda\right)\left[c - sF\left(q^{cc*}\right)\right] + \left[w^{rc1} - sF\left(q^{cc*}\right)\right]sf\left(q^{cc*}\right)\left(dq^{cc*}/\lambda\right)}{\left[c - sF\left(q_C^*\right)\right]^2} \\ &= \frac{-\left[c - sF\left(q^{cc*}\right)\right] + \left[w - sF\left(q^{cc*}\right)\right]}{\left[c - sF\left(q^{cc*}\right)\right]^2}sf\left(q^{cc*}\right)\frac{dq^{cc*}}{\lambda} = \frac{\left(w^{rc1} - c\right)}{\left[c - sF\left(q^{cc*}\right)\right]^2}sf\left(q^{cc*}\right)\frac{dq^{cc*}}{\lambda} > 0. \end{aligned} \tag{A.53}$$

For $\phi_2 = w^{rc2}/c$, ϕ_2 is independent of λ obviously. □

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This paper was partly supported by (i) National Natural Science Foundation of Zhjiang Province [Grant no. LY18G010016], (ii) Zhoushan Science and Technology Project [Grant no. 2017C41018], (iii) the Open Foundation from Marine Sciences in the Most Important Subjects of Zhejiang [Grant no. 20130212], (iv) the Open Foundation from Fishery Sciences in the First-Class Subjects of Zhejiang [Grant no. 20160023], and (v) the Startup Foundation of Zhejiang Ocean University [Grant no. 11085090318].

References

[1] P. Heidhues and B. Koszegi, "Competition and price variation when consumers are loss averse," *American Economic Review*, vol. 98, no. 4, pp. 1245–1268, 2008.

[2] J. Nasiry and I. Popescu, "Dynamic pricing with loss-averse consumers and peak-end anchoring," *Operations Research*, vol. 59, no. 6, pp. 1361–1368, 2011.

[3] O. Baron, M. Hu, S. Najafi-Asadolahi, and Q. Qian, "Newsvendor selling to loss-averse consumers with stochastic reference points," *Manufacturing and Service Operations Management*, vol. 17, no. 4, pp. 456–469, 2015.

[4] Z. Hu and J. Nasiry, "Are markets with loss-averse consumers more sensitive to losses?" *Management Science*, vol. 64, no. 3, pp. 1384–1395, 2018.

[5] R. Thaler, "Toward a positive theory of consumer choice," *Journal of Economic Behavior & Organization*, vol. 1, no. 1, pp. 39–60, 1980.

[6] D. Kahneman, J. L. Knetsch, and R. H. Thaler, "Anomalies: the endowment effect, loss aversion, and status quo bias," *Journal of Economic Perspectives*, vol. 5, no. 1, pp. 193–206, 1991.

[7] X. Q. Cai, J. Chen, Y. B. Xiao, and X. L. Xu, "Optimization and coordination of fresh product supply chains with freshness keeping efforts," *Production and Operations Management*, vol. 19, no. 3, pp. 61–78, 2010.

[8] Q. Wu, Y. Mu, and Y. Feng, "Coordinating contracts for fresh product outsourcing logistics channels with power structures," *International Journal of Production Economics*, vol. 160, pp. 94–105, 2015.

[9] Y. Yu and T. Xiao, "Pricing and cold-chain service level decisions in a fresh agri-products supply chain with logistics outsourcing," *Computers & Industrial Engineering*, vol. 111, pp. 56–66, 2017.

[10] X. Xu, "Optimal price and product quality decisions in a distribution channel," *Management Science*, vol. 55, no. 8, pp. 1347–1352, 2009.

[11] G. Xie, W. Yue, S. Wang, and K. K. Lai, "Quality investment and price decision in a risk-averse supply chain," *European Journal of Operational Research*, vol. 214, no. 2, pp. 403–410, 2011.

[12] K. Jerath, S. Kim, and R. Swinney, "Product quality in a distribution channel with inventory risk," *Working Paper*, 2017.

[13] M. Leng, Z. Li, and L. Liang, "Implications for the role of retailers in quality assurance," *Production Engineering Research and Development*, vol. 25, no. 5, pp. 779–790, 2016.

[14] H. Yang and W. Chen, "Retailer-driven carbon emission abatement with consumer environmental awareness and carbon tax: revenue-sharing versus cost-sharing," *The International Journal of Management Science*, no. 78, pp. 179–191, 2018.

[15] Y.-K. Che, "Customer return policies for experience goods," *The Journal of Industrial Economics*, vol. 44, no. 1, pp. 17–24, 1996.

[16] S. Davis, E. Gerstner, and M. Hagerty, "Money back guarantees in retailing: matching products to consumer tastes," *Journal of Retailing*, vol. 71, no. 1, pp. 7–22, 1995.

[17] X. Su, "Consumer returns policies and supply chain performance," *Manufacturing & Service Operations Management*, vol. 11, no. 4, pp. 595–612, 2009.

[18] T. Xiao, K. Shi, and D. Yang, "Coordination of a supply chain with consumer return under demand uncertainty," *International Journal of Production Economics*, vol. 124, no. 1, pp. 171–180, 2010.

[19] J. Chen and P. Bell, "The impact of customer returns on decisions in a newsvendor problem with and without buyback policies," *International Transactions in Operational Research*, vol. 18, no. 4, pp. 473–491, 2011.

[20] W. Hu, Y. Li, and K. Govindan, "The impact of consumer returns policies on consignment contracts with inventory control," *European Journal of Operational Research*, vol. 233, no. 2, pp. 398–407, 2014.

[21] J. Chen and P. C. Bell, "The impact of customer returns on pricing and order decisions," *European Journal of Operational Research*, vol. 195, no. 1, pp. 280–295, 2009.

[22] J. Chen and P. C. Bell, "The impact of customer returns on supply chain decisions under various channel interactions," *Annals of Operations Research*, vol. 206, pp. 59–74, 2013.

[23] D. Vlachos and R. Dekker, "Return handling options and order quantities for single period products," *European Journal of Operational Research*, vol. 151, no. 1, pp. 38–52, 2003.

[24] J. Mostard and R. Teunter, "The newsboy problem with resalable returns: a single period model and case study," *European Journal of Operational Research*, vol. 169, no. 1, pp. 81–96, 2006.

[25] R. Ruiz-Benitez and A. Muriel, "Consumer returns in a decentralized supply chain," *International Journal of Production Economics*, vol. 147, no. C, pp. 573–592, 2014.

[26] X. Chen and Q. Zhou, "Loss-averse retailer's optimal ordering policies for perishable products with customer returns," *Mathematical Problems in Engineering*, vol. 2014, Article ID 831796, 5 pages, 2014.

[27] J. Chen and B. Chen, "Competing with customer returns policies," *International Journal of Production Research*, vol. 54, no. 7, pp. 2093–2107, 2016.

[28] T. Choi and S. Guo, "Responsive supply in fashion mass customisation systems with consumer returns," *International Journal of Production Research*, vol. 56, no. 10, pp. 3409–3422, 2017.

[29] S. H. Yoo, D. S. Kim, and M.-S. Park, "Pricing and return policy under various supply contracts in a closed-loop supply chain," *International Journal of Production Research*, vol. 53, no. 1, pp. 106–126, 2015.

[30] D. Kahneman and A. Tversky, "Prospect theory: an a nalysis of decision under risk," *Econometrica*, vol. 47, no. 2, pp. 263–292, 1979.

[31] M. E. Schweitzer and G. P. Cachon, "Decision bias in the newsvendor problem with a known demand distribution: experimental evidence," *Management Science*, vol. 46, no. 3, pp. 404–420, 2000.

[32] C. X. Wang and S. Webster, "The loss-averse newsvendor problem," *Omega* , vol. 37, no. 1, pp. 93–105, 2009.

[33] C. X. Wang, "The loss-averse newsvendor game," *International Journal of Production Economics*, vol. 124, no. 2, pp. 448–452, 2010.

[34] C. X. Wang and S. Webster, "Channel coordination for a supply chain with a risk-neutral manufacturer and a loss-averse retailer," *Decision Sciences*, vol. 38, no. 3, pp. 361–389, 2007.

[35] D. Kahneman and A. Tversky, "Choices, values, and frames," *American Psychologist*, vol. 39, no. 4, pp. 341–350, 1984.

[36] A. Tversky and D. Kahneman, "The framing of decisions and the psychology of choice," *American Association for the Advancement of Science: Science*, vol. 211, no. 4481, pp. 453–458, 1981.

[37] R. Thaler, "Mental accounting and consumer choice," *Marketing Science*, vol. 4, no. 3, pp. 199–214, 1985.

[38] R. H. Thaler, "Menta accounting matters," *Journal of Behavioral Decision Making*, vol. 12, no. 3, pp. 183–206, 1999.

[39] H. Teck-Hua and Z. Juanjuan, "Designing pricing contracts for boundedly rational customers: does the framing of the fixed fee matter?" *Management Science*, vol. 54, no. 4, pp. 686–700, 2008.

[40] M. Becker-Peth, E. Katok, and U. W. Thonemann, "Designing buyback contracts for irrational but predictable newsvendors," *Management Science*, vol. 59, no. 8, pp. 1800–1816, 2013.

[41] A. M. Davis, E. Katok, and N. Santamaría, "Push, pull, or both? A behavioral study of how the allocation of inventory risk affects channel efficiency," *Management Science*, vol. 60, no. 11, pp. 2666–2683, 2014.

[42] Y. Zhang, K. Donohue, and T. H. Cui, "Contract preferences and performance for the loss-averse supplier: buyback vs. revenue sharing," *Management Science*, vol. 62, no. 6, pp. 1734–1754, 2016.

[43] G. Samatli-Pac and W. Shen, "Pricing and customer returns policies with loss averse customers," in *Proceedings of the Seventh International Conference on Management Science and Engineering Management*, J. Xu, J. A. Fry, B. Lev, and A. Hajiyev, Eds., vol. 1, pp. 661–674, Springer-Verlag, 2014.

[44] B. F. Liao and B. Y. Li, "A marketing strategy in a closed-loop supply chain with loss-averse consumers," *Mathematical Problems in Engineering*, vol. 2018, Article ID 2560153, 9 pages, 2018.

[45] G. H. Chao, S. M. R. Iravani, and R. C. Savaskan, "Quality improvement incentives and product recall cost sharing contracts," *Management Science*, vol. 55, no. 7, pp. 1122–1138, 2009.

[46] Y. Li, L. Xu, and D. Li, "Examining relationships between the return policy, product quality, and pricing strategy in online direct selling," *International Journal of Production Economics*, vol. 144, no. 2, pp. 451–460, 2013.

[47] G. P. Cachon and M. A. Lariviere, "Supply chain coordination with revenue-sharing contracts: strengths and limitations," *Management Science*, vol. 51, no. 1, pp. 30–44, 2005.

[48] R. E. Barlow and F. Proschan, *Statistical Theory of Reliability and Life Testing: Probability Models*, Holt, Rinehart and Winston, New York, NY, USA, 1975.

[49] N. C. Petruzzi and M. Dada, "Pricing and the newsvendor problem: a review with extensions," *Operations Research*, vol. 47, no. 2, pp. 183–194, 1999.

[50] B. A. Pasternack, "Optimal pricing and return policies for perishable commodities," *Marketing Science*, vol. 4, no. 2, pp. 166–176, 1985.

[51] F. Bernstein and A. Federgruen, "Decentralized supply chains with competing retailers under demand uncertainty," *Management Science*, vol. 51, no. 1, pp. 18–29, 2005.

[52] J. Zhang, G. Liu, Q. Zhang, and Z. Bai, "Coordinating a supply chain for deteriorating items with a revenue sharing and cooperative investment contract," *The International Journal of Management Science*, vol. 56, no. 3, pp. 37–49, 2015.

[53] S. R. Bhaskaran and V. Krishnan, "Effort, revenue, and cost sharing mechanisms for collaborative new product development," *Management Science*, vol. 55, no. 7, pp. 1152–1169, 2009.