INFORMATION SHARING STRATEGY FOR AN INCUMBENT RETAILER IN A CLOSED-LOOP SUPPLY CHAIN

KEYUAN CAI¹, QIANJIANG YIN¹ AND DALI HUANG²,*

Abstract. This paper considers a closed-loop supply chain with a manufacturer, an incumbent retailer and an entrant retailer. The two retailers order the same products from the common manufacturer and then sell to consumers, and the incumbent retailer possesses private forecast information with respect to the uncertain demand. The incumbent retailer could strategically share its forecast information to make great profits. We find that, when the incumbent retailer shares the information with its upstream manufacturer, the entrant retailer benefits from this information sharing arrangement because of the information leakage effect. However, the incumbent retailer will be motivated to share the information with the manufacturer only when the manufacturer is highly efficient in collection investment. To achieve information sharing, the research results show that, the manufacturer and the entrant retailer should pay the incumbent retailer for the demand information if the investment efficiency of the manufacturer meets certain conditions.

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1. Introduction

Many used products, especially the waste electrical and electronic equipment (WEEE) in which there are more than 350 toxic materials, do great harm to human health once they are not be handled appropriately [40]. The collection and remanufacturing of used products could reduce the landfill space and air pollution, which make great contribution to the environment. In order to force the manufacturers to take the environmental responsibility, many countries, such as America, Japan and China, enact the corresponding regulations and legislations to compel the producers to collect and recycle their used products [15]. In addition to the above environmental benefits, in some real-cases, the collection and remanufacturing of used products could also create economic benefits for the companies. For example, Xerox and Canon save several million dollars through engaging in the remanufacturing activities [58]. As a result, on account of the economic and environmental factors, the remanufacturing in the closed-loop supply chain (CLSC) is attracting extensive attention for the managers and researchers [32]. In practice, the manufacturers usually undertake the used product collection and remanufacturing activities. For instance, the camera manufacturer, Fuji Photo Film, collects and remanufactures...
used cameras in the market, and most consumers don’t perceive that the cameras they buy are remanufactured products [48].

Nowadays, with the rapid changes of market environment, the market demand of products is full of uncertainty. As a result, the forecast information about product demand becomes a key resource for the companies [30]. In the operations management, it is generally considered that complete information sharing is helpful for the decisions of supply chain participants, and is helpful to increase the system profits. For example, Wal-Mart routinely analyzes its product-sale data and then shares the future demand information with its suppliers. This information sharing behavior brings great benefits for the Wal-Mart. However, in 2001, Wal-Mart announced that it would stop sharing the product demand information to its outside corporations for the reason that the latter may sell the information to its competitors, which would hurt its profits [42].

In real life, since the incumbent retailer has sold the products directly to the consumers for a long time, she will know more about the consumer market than both the manufacturer and the entrant retailer. The incumbent retailer usually possesses precise information on market demand that the rest of the supply chain is not available [1,36]. Taking the smart TV industry as an example, TCL and Xiaomi are two famous smart TV manufacturers. They purchase a core TV-screen from Samsung. TCL, which is a traditional TV manufacturer, launched a dual-screen smart TV in 2018. In the meanwhile, Xiaomi, as an entrant, also launched a new smart TV product. They created competition in the market. Nevertheless, TCL, as an incumbent retailer in the market, possesses the market information regarding the market demand and consumer preferences. It can strategically choose to share it or not to obtain more profits [23].

To date, although some literature investigates the demand information sharing strategy in the CLSC, the case of the combination between demand information sharing and retailer competition in the CLSC has not been considered yet. However, as shown above, in practice, many manufacturers engage in the collection and remanufacturing activities of used products. And it is very common that an entrant retailer enters a market to compete with an incumbent retailer in real-world business. Based on the above factual background, our aim is to address the following questions: (1) Under what conditions does the incumbent retailer have the motivation to share its demand forecast information? (2) What is the effect of the incumbent retailer’s information sharing strategies on other CLSC participants? We consider a CLSC made up of an incumbent retailer, an entrant retailer and a common manufacturer. The manufacturer is in charge of collection and remanufacturing of used products and new product production. The two retailers purchase the same products from the manufacturer, and then sell them to consumers. Based on the market advantage, the incumbent retailer possesses private forecast information about product demand. It can strategically share the information with other CLSC participants to make great profits. In this paper, we consider that if the common manufacturer obtains the forecast information of the incumbent retailer, the entrant retailer could infer the forecast information through the manufacturer’s decisions, which are made according to the demand forecast information. This information leakage effect has been extensively investigated in the literature on the demand forecast information sharing (e.g., [25,55]). Hence, from the perspective of the model, we consider three information sharing scenarios: (1) No information sharing exists in the CLSC; (2) The incumbent retailer shares its forecast information with the entrant retailer; (3) The incumbent retailer shares the information with the manufacturer. Then we compare the three models to acquire some managerial insights. Based on the above description, our research belongs to the research stream on CLSC management, which has been investigated widely. A representative study is Savaskan et al. [34] in which three CLSC models with product remanufacturing are explored. In this paper, we model a similar remanufacturing process as in Savaskan et al. [34] and explore the information sharing problem in our CLSC structure.

Game theory is an important method for solving the benefit balance problems among different objects. As a basic research tool, this method has been widely applied to study the supply chain management issues. Thus, our paper employs a game-theoretic approach to model the decision-making process of the CLSC members. Also, we obtain each models’ equilibrium solutions by using the backward induction method, which is an important reasoning method in game theory. The key managerial insights of this study are as follows. First, the manufacturer’s collection investment efficiency and the incumbent retailer’s information sharing strategies play important roles in CLSC participants’ decisions. Second, the incumbent retailer’s information sharing with the
manufacturer or the entrant retailer always makes the entrant retailer better off. Third, when the manufacturer is highly efficient in collection investment, the incumbent retailer would benefit from sharing its demand forecast information with the manufacturer. Fourth, the entrant retailer is not able to acquire the incumbent retailer’s demand forecast information through a side payment.

Our paper’s main contributions are presented as follows. First, we explore the incentives for information sharing in a competing CLSC, where the incumbent retailer could strategically choose to share its demand forecast information with the common manufacturer or the entrant retailer. Our paper contributes to the extant literature through examining the influence of collection investment efficiency on the information sharing achievement. Second, our research presents the impact of different information sharing strategies on the optimal decisions of CLSC participants, which provides insights for the participants to make better decisions. Third, through comparing the equilibrium results among three information sharing scenarios, we characterize the possibility that whether the information sharing could be achieved by a side payment. Our work not only enriches the literature on CLSC and demand information sharing but also provides valuable managerial insights for enterprise managers.

The rest of this paper is organized as follows. Section 2 presents the relevant literature review. In Section 3, we construct the three information sharing models. In Section 4, we solve three models with information sharing considered, and get the equilibrium solutions. In Section 5, we compare the equilibrium solutions under different scenarios and present the influence of different information sharing strategies. Section 6 proposes the possibility that acquiring information of the incumbent retailer by a payment. Section 7 presents a numerical study to further verify our findings and Section 8 describes conclusions based on this paper and proposes future work.

2. Literature review

Our paper mainly draws on and contributes to three streams of literature: (i) demand information sharing in a supply chain with competition, (ii) remanufacturing in a CLSC, and (iii) competition between incumbent firms and entrant firms.

2.1. Demand information sharing in a competing supply chain

In the last decades, scholars have made great efforts to explore the incentives for demand information sharing within a supply chain made up of one upstream manufacturer selling to n downstream competing retailers (e.g., [2, 3, 24, 25, 35, 38]). This line of research considers that all the retailers have respective product demand information and investigates the effect of different factors on the information sharing incentives. Our paper aims to explore the effect of collection investment efficiency on the intention about sharing information in a supply chain structure which consists of once upstream manufacturer and two downstream competing retailers. Based on this supply chain structure, several researchers explore the incentive issues of demand information sharing from different aspects. Zhang [53] considers that the two retailers possess private demand forecast information, and studies the incentive issue of information sharing under Cournot and Bertrand competition. Recently, Li et al. [26] continues the work of Zhang [53]. They further consider that the manufacturer could acquire information about product demand at a cost and explore whether the manufacturer could lead the retailers to share their private demand forecast information through subsidization strategies. Gal-Or et al. [11] suppose that all the manufacturer and the two retailers possess product demand signals. They study the impact of the inference effect resulting from a pricing distortion on the supply chain. Jiang and Hao [19] consider that each retailer has a demand signal, which can be exchanged between them. They explore the influences about the competition of retailers and supplier on the demand information sharing. Zhou et al. [58] study a supply chain made up of one group purchasing organization and two competing manufacturers. Manufactures buy a same component from the group purchasing organization and have respective private demand forecast information. They discuss the influence of horizontal competition and information incompletion on the incentives to share information. Although the preceding studies have investigated the demand information sharing issue in a supply chain with competition, they mainly consider a forward supply chain. In reality, in accordance with the environmental
protection regulations, many companies start to collect their used products and remanufacture them, thereby forming a CLSC of the firm. In this paper, we insert the theme of demand information sharing into a competing CLSC. Our work reveals the role of collection investment efficiency in achieving demand information sharing. Thus, our paper complements this line of literature.

2.2. Remanufacturing in a CLSC

Due to the importance of environmental protection, a large body of studies investigate the remanufacturing activities of used products in a CLSC. Savaskan et al. [33] examine the impacts of the collection channel choice on product pricing strategies in a CLSC with retailer competition. Wu and Zhou [48] studies the effect of supply chain competition on the collection channel choice in a closed-loop supply chain considering the manufacturer-managed or the retailer-managed collection. Zheng et al. [56] investigate the impact of different power structure (i.e., manufacturer-Stakelberg, retailer-Stakelberg and Nash) on the performance of the CLSC with manufacturer encroachment. Wang et al. [44] discuss a dominant retailer’s collection decision in a CLSC with upstream competition, and derive that when the upstream competition is intense, the manufacturer should undertake more collection responsibility. Mondal and Giri [28] study the impact of cap-and-trade policy on retailers’ competition and cooperation strategies in a CLSC. The above researches consider the case where manufacturers undertake the collection and remanufacturing activities. In this situation, the third-party collector or the retailer is the undertaker of collection activities is also extensively explored by the scholars (e.g., [7, 9, 18, 27, 29, 40, 43]). All these researches study related problems with a same assumption that the product demand is certain and is common information. However, in practice, because of the changes of market environment, the future demand of products is usually uncertain. And it is common that the demand forecast information that is used by the firms is private. Recently, several literatures have paid attention to this issue. Hosoda et al. [13] consider that the market demands and product returns are uncertain, and explore the advantages for information sharing. Huang and Wang [15] study the effect of demand information sharing in a CLSC with technology licensing under different remanufacturing scenarios. Zhang and Xiong [54] discuss the problem about the information sharing in a CLSC by considering one manufacturer and one retailer. They assume that they both own the demand forecast information. Huang and Wang [17] analyze the interaction effect between information sharing and learning effect in a CLSC while technology licensing exists. Wang et al. [46] explore the impacts of information sharing modes on a dual-channel CLSC under different power structures, and derive that the sharing of demand information benefits the manufacturer under a collector Stackelberg scenario. Xia et al. [49] study the optimal financing and production strategies in a CLSC with an original equipment manufacturer (OEM), and a risk-averse authorized remanufacturer (RM). They find that consumer surplus always decreases with RM’s risk aversion level when considering financing. It is worth pointing out that a typical related literature is Savaskan et al. [34]. In the study of Savaskan et al. [34], they consider a CLSC in which the used product collector can be a manufacturer, a retailer or a third party. They mainly investigate the problem of choosing the appropriate collector. They use game theory to model the decision-making process of the CLSC member in each collection scenario. By using backward induction method, they obtain the equilibrium solutions under different collection scenarios. Through comparing the equilibrium solutions, their research results show that the most effective collector is the retailer. Different from their work, we consider a CLSC in which the incumbent retailer has private demand forecast information. We mainly explore the information sharing strategy of the incumbent retailer. We adopt game theory to model the different information sharing cases, and find the equilibrium solutions in each case by backward induction. Our research results show that when the manufacturer is highly efficient in collection investment, the incumbent retailer should share demand forecast information with the manufacturer. Based on the above literature, we can see that the CLSC has attracted much attention of scholars in recent years. However, none of these studies investigate the problem of demand information sharing in a competitive scenario, which is the focus of our work.
Table 1. Differences between our paper and the most related studies.

<table>
<thead>
<tr>
<th>Paper</th>
<th>Demand information sharing</th>
<th>CLSC</th>
<th>Competition between incumbent retailer and entrant retailer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zhang [53]</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Li et al. [26]</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Savaskan et al. [33]</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Wang et al. [46]</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Anand and Goyal [1]</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Lei et al. [23]</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>This paper</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

2.3. Competition between incumbent firms and entrant firms

Our paper is also related to the studies with respect to competition between incumbent firms and entrant firms. The extant research on this stream mainly focuses on setting up barriers or obtaining benefits by different strategies during the competition (e.g., [4, 21, 31, 41, 51, 59]). In recent decades, some scholars focus on the information sharing of a supply chain by considering competition between incumbents and entrants. Anand and Goyal [1] explore a supply chain consisting of an incumbent retailer, an entrant retailer and a supplier, and the incumbent retailer could acquire the demand information. They explore the influences of information leakage in a supply chain. In response to the information leakage issue in the above paper, Kong et al. [22] try to ease the negative impacts of information leakage by adopting revenue-sharing contracts. Shamir and Shin [36] study two competing supply chains, and the incumbent retailer have a private signal with respect to the product demand. They explore how information sharing affects the corporations’ operational decisions. Wang et al. [42] consider that the dominant incumbent retailer possesses private information about the demand state. They discuss the effects of information concealment. Chen and Özer [6] consider that both the incumbent retailer and the entrant have the demand forecast information, whereas the incumbent retailer’s demand forecast is more accurate. They explore how to prevent information leakage through contracts. Lei et al. [23] explores a supply chain made up of a common supplier and two competing retailers, and the incumbent retailer have private demand state information. They investigate the information sharing strategies for the incumbent retailer. Yu and Cao [52] examine the impacts of carbon emission abatement on the sharing of information in the supply chain. They show that, the carbon emission abatement owns an important position in the incumbent retailer’s information sharing decisions. Our paper builds a similar supply chain structure. As compared with this research stream, a significant difference between our paper and their work is that we address the effect of collection and remanufacturing of used products on demand forecast information sharing. Interestingly, our paper reveals a critical different finding that the impacts of different information sharing scenarios on the profitability of the CLSC participants depend on the manufacturer’s collection investment efficiency.

In summary, this paper contributes to the extant related studies in two aspects. First, we examine the demand information sharing problem of a CLSC, considering the competition between the entrant retailer and the incumbent retailer who owns the demand forecast information. This problem is common in practice but is a new topic in the literature. Second, we take the manufacturer’s collection investment into consideration, which enables us to explore its influence on the CLSC firms’ profitability under different information sharing scenarios. Moreover, the demand information acquisition issue is investigated and remarkable results are found in this CLSC structure. We summarize the differences between our paper and the most related studies in Table 1.
3. The model

In this paper, we extend the model (model \(M\)) in Savaskan et al. \[34\]. We explore a CLSC that consists one common manufacturer and two retailers. The manufacturer is responsible for collection and remanufacturing of used products. The collection rate of the manufacturer is \(\tau\). As in Savaskan et al. \[34\], we employ a quadratic cost function \(k\tau^2\) to describe the investment in used product collection, where \(k\) refers to the scaling parameter. Note that \(k\) captures the investment cost-efficiency. A higher \(k\) denotes a lower investment efficiency because it incurs a higher cost for the same collection rate. The collection and handling cost of a returned unit is \(B\).

The manufacturer produces a new product with raw materials at a cost \(c_m\), and produces a new product with a returned product at a cost \(c_r\). We consider that \(c_r < c_m\), which means that it is more costly by producing a new product than remanufacturing a used product. Assume that \(\Delta = c_m - c_r > B\), that is, the remanufacturing process of the manufacturer is economically viable \[7,9\]. Hence, the average unit cost of producing a new product is \(\tau c_r + (1 - \tau) c_m = c_m - \Delta \tau\).

We consider two retailers who order the same products from the common manufacturer: one incumbent retailer who has sold the products directly to the consumers for a period of time, one entrant retailer who just enters the market. The wholesale price of products is \(w\). Regard \(q_i\) and \(q_e\) as the order quantities of the incumbent retailer and entrant retailer, respectively. The investigated CLSC structure in this paper is shown in Figure 1.

In line with Wang et al. \[42\] and Yu and Cao \[52\], the retail price of the products is \(p = a - q_i - q_e\), where \(a\) is the potential market demand of the products. In our model, we consider that the product demand is uncertain for the reason that the business conditions change. Hence, \(a\) is a random variable. Suppose \(a = a_0 + e\), where \(a_0\) represents the certain mean demand, and \(e\) captures the uncertain demand, which follows a normal distribution with mean 0 and variance \(V\). Since the incumbent retailer has sold the products directly to the consumers for a long time, the incumbent retailer has the historical sales data and knows the market better. The incumbent retailer could make a market demand forecast about the products \[12,42,52\]. Let \(f = a + \varepsilon\) indicates the forecast demand, where \(\varepsilon\) is the error term, which follows a normal distribution with mean 0 and variance \(S\). Note that \(\varepsilon\) and \(e\) are independent \[8,10,39,45\]. Hence, the information structure is shown as follows:

\[
E(a|f) = \frac{S}{V + S} a_0 + \frac{V}{V + S} f = (1 - \rho) a_0 + \rho f \equiv A, \tag{1}
\]

\[
E[(f - a_0)^2] = E[(\varepsilon + \varepsilon)^2] = V + S, \tag{2}
\]
where $\rho = V/(V + S)$, which refers to the incumbent retailer’s forecast accuracy, which correlates with $S$ negatively.

The demand forecast information of the incumbent retailer is private. She could select to share the information with other participants in the CLSC or not. The objective of this paper is to explore the impacts of the incumbent retailer’s different information sharing strategies on the CLSC. In consistent with Ha et al. [12], we suppose that the information shared by the incumbent retailer is true whatever the information sharing strategy she chooses. In reality, the shared information is usually the tangible and verifiable sales data, and false information could jeopardize long-term relationship. Similar to Yu and Cao [52], the sequence of events in this CLSC is shown as below: Firstly, the incumbent retailer makes a demand forecast about the products and chooses whether to share the forecast information with other CLSC participants. Secondly, the manufacturer decides the collection rate and the wholesale price of products according to the available information. Thirdly, the incumbent retailer and entrant retailer order the products from the manufacturer and sell them to the consumers.

Based on the CLSC structure shown in Figure 1, there are four information sharing scenarios: (1) the incumbent retailer doesn’t share the forecast information in the CLSC, (2) the incumbent retailer shares information with the entrant retailer, (3) the incumbent retailer shares information with the manufacturer, (4) the incumbent retailer shares information with both the manufacturer and the entrant retailer. Note that when the incumbent retailer shares its forecast information with the manufacturer, the latter would adjust its collection rate and wholesale price according to the forecast information. Consequently, the entrant retailer could infer the forecast information based on the adjusted collection rate and wholesale price. This information leakage effect is extensively explored in the literature about demand forecast information sharing (e.g., [20, 24, 25, 55]). In our model, we also consider this information leakage effect. Hence, the information sharing scenario 3 is the same with the information sharing scenario 4. Next, we examine these information sharing scenarios and study the impact of different information sharing strategies of the incumbent retailer on the CLSC.

We present the notations of our model in the following Table 2.

### 4. INFORMATION SHARING SCENARIOS

In this section, we establish models to examine the various information sharing scenarios. And we obtain the equilibrium solutions of each scenario by backward induction. Similar to Savaskan et al. [34], to ensure positive the equilibrium solutions, we suppose that $k > (\Delta - B)^2/6$, i.e., it will not be too much cheap while making the investment for used products collection. Furthermore, $\pi_m$, $\pi_i$, $\pi_e$ and $\pi_{sc}$ represent the expected profit of the manufacturer, the incumbent retailer, the entrant retailer and whole CLSC, respectively. Superscripts NI, SE and SS stand for the information sharing scenarios 1, 2 and 3, respectively.

#### 4.1. Scenario 1: no information sharing (NI)

In this scenario, the incumbent retailer doesn’t share its forecast information with other CLSC members. Consequently, the entrant retailer and the manufacturer only know the mean value of product demand. Thus, the CLSC participants’ decision functions can be given by

$$
\max_{\tau, w} E(\pi^{\text{NI}}_m) = E[(w - c_m + (\Delta - B)\tau)(q_i + q_e) - k\tau^2],
$$

$$
\max_{q_i} E(\pi^{\text{NI}}_i | f) = E[(a - q_i - q_e - w)q_i | f],
$$

$$
\max_{q_e} E(\pi^{\text{NI}}_e) = E[(a - q_i - q_e - w)q_e].
$$

We solve the optimization problem through backward induction. The equilibrium results are presented in Lemma 1. The proof of Lemma 1 is given in Appendix A.
Table 2. Summary of notations.

<table>
<thead>
<tr>
<th>Notation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a$</td>
<td>The potential market demand of the products</td>
</tr>
<tr>
<td>$a_0$</td>
<td>Mean market demand</td>
</tr>
<tr>
<td>$\tau$</td>
<td>Collection rate (decision variable)</td>
</tr>
<tr>
<td>$w$</td>
<td>Wholesale price of the products (decision variable)</td>
</tr>
<tr>
<td>$q_i$</td>
<td>Order quantity of the incumbent retailer (decision variable)</td>
</tr>
<tr>
<td>$q_e$</td>
<td>Order quantity of the entrant retailer (decision variable)</td>
</tr>
<tr>
<td>$k$</td>
<td>Investment cost coefficient of used product collection</td>
</tr>
<tr>
<td>$c_m$</td>
<td>Unit production cost of producing a new product with raw materials</td>
</tr>
<tr>
<td>$c_r$</td>
<td>Unit production cost of producing a new product with returned products</td>
</tr>
<tr>
<td>$B$</td>
<td>The collection and handling cost of a returned unit</td>
</tr>
<tr>
<td>$\Delta$</td>
<td>Unit saving cost of remanufacturing, $\Delta &gt; B$</td>
</tr>
<tr>
<td>$f$</td>
<td>The incumbent retailer’s demand forecast information</td>
</tr>
<tr>
<td>$A$</td>
<td>Forecast expected value of market demand</td>
</tr>
<tr>
<td>$e$</td>
<td>Uncertain part of the product demand</td>
</tr>
<tr>
<td>$\varepsilon$</td>
<td>Error term of forecast</td>
</tr>
<tr>
<td>$V$</td>
<td>Variance of uncertain demand</td>
</tr>
<tr>
<td>$S$</td>
<td>Variance of forecast</td>
</tr>
<tr>
<td>$\rho$</td>
<td>Forecasting accuracy, $\rho = V/(V + S)$ and $0 &lt; \rho &lt; 1$</td>
</tr>
<tr>
<td>$\pi_m$</td>
<td>The manufacturer’s expected profit</td>
</tr>
<tr>
<td>$\pi_i$</td>
<td>The incumbent retailer’s expected profit</td>
</tr>
<tr>
<td>$\pi_e$</td>
<td>The entrant retailer’s expected profit</td>
</tr>
<tr>
<td>$\pi_{sc}$</td>
<td>The whole CLSC’s expected profit</td>
</tr>
</tbody>
</table>

Lemma 1. Under NI scenario, the optimal wholesale price $w_{NI}^*$, the optimal collection rate $\tau_{NI}^*$, the incumbent retailer’s optimal order quantity $q_{NIi}^*$ and the entrant retailer’s optimal order quantity $q_{NIe}^*$ are given by

\[
\begin{align*}
    w_{NI}^* &= \frac{3k(a_0 + c_m) - a_0(\Delta - B)^2}{6k-(\Delta - B)^2}, \\
    \tau_{NI}^* &= \frac{(a_0 - c_m)(\Delta - B)}{6k-(\Delta - B)^2}, \\
    q_{NIi}^* &= \frac{2k(3A - 2a_0 - c_m) + (a_0 - A)(\Delta - B)^2}{2[6k-(\Delta - B)^2]}, \\
    q_{NIe}^* &= \frac{k(a_0 - c_m)}{6k-(\Delta - B)^2}.
\end{align*}
\] (6)

Then, the manufacturer’s expected profit $\pi_{mNI}^*$, the incumbent retailer’s expected profit $\pi_{iNI}^*$, the entrant retailer’s expected profit $\pi_{eNI}^*$, and the expected profit of the whole CLSC $\pi_{scNI}^*$ are given by

\[
\begin{align*}
    \pi_{mNI}^* &= \frac{k(a_0 - c_m)^2}{6k-(\Delta - B)^2}, \\
    \pi_{iNI}^* &= \frac{k^2(a_0 - c_m)^2}{[6k-(\Delta - B)^2]^2} + \frac{\rho V}{4}, \\
    \pi_{eNI}^* &= \frac{k^2(a_0 - c_m)^2}{[6k-(\Delta - B)^2]^2}, \\
    \pi_{scNI}^* &= \frac{k(a_0 - c_m)^2[8k-(\Delta - B)^2]}{[6k-(\Delta - B)^2]^2} + \frac{\rho V}{4}.
\end{align*}
\] (8)

Lemma 1 states that the unique equilibrium solutions exist under this scenario. It shows that the incumbent retailer’s optimal order quantity $(q_{NIi}^*)$ increases with the demand forecast value $(A)$. That’s because a larger $A$ stands for a higher demand. Naturally, the incumbent retailer will order more products. Moreover, the expected profit of the incumbent retailer $(\pi_{iNI}^*)$ increases in the forecast accuracy $(\rho)$. It is intuitive that a more accurate forecast is better for the incumbent retailer.
4.2. Scenario 2: sharing information with the entrant retailer (SE)

In this case, the entrant retailer obtains the shared information from the incumbent retailer. Consequently, the entrant retailer has the forecast information, but the manufacturer only knows the mean value of product demand. Hence, the CLSC participants’ decision functions are shown as follows:

\[
\max_{\tau,w} E(\pi_m^{SE}) = E[(w - c_m + (\Delta - B)\tau)(q_i + q_e) - k\tau^2],
\]
\[
\max_{q_i} E(\pi_i^{SE}|f) = E[(a - q_i - q_e - w)q_i|f],
\]
\[
\max_{q_e} E(\pi_e^{SE}|f) = E[(a - q_i - q_e - w)q_e|f].
\]

We address the optimization problem in the same way as in the scenario 1. The equilibrium results are concluded in Lemma 2.

**Lemma 2.** Under SE scenario, the optimal wholesale price \(w^{SE^*}\), the optimal collection rate \(\tau^{SE^*}\), the incumbent retailer’s optimal order quantity \(q_i^{SE^*}\) and the entrant retailer’s optimal order quantity \(q_e^{SE^*}\) are given by

\[
w^{SE^*} = \frac{3k(a_0 + c_m) - a_0(\Delta - B)^2}{6k-(\Delta - B)^2}, \quad \tau^{SE^*} = \frac{(a_0 - c_m)(\Delta - B)}{6k-(\Delta - B)^2},
\]
\[
q_i^{SE^*} = q_e^{SE^*} = \frac{k(6A - 3a_0 - 3c_m) + (a_0 - A)(\Delta - B)^2}{3[6k-(\Delta - B)^2]}.
\]

Then, the manufacturer’s expected profit \(\pi_m^{SE^*}\), the incumbent retailer’s expected profit \(\pi_i^{SE^*}\) and the entrant retailer’s expected profit \(\pi_e^{SE^*}\), and the expected profit of the whole CLSC \(\pi_{sc}^{SE^*}\) are given by

\[
\pi_m^{SE^*} = \frac{k(a_0 - c_m)^2}{6k-(\Delta - B)^2}, \quad \pi_i^{SE^*} = \frac{k^2(a_0 - c_m)^2}{[6k-(\Delta - B)^2]^2} + \frac{\rho V}{9},
\]
\[
\pi_e^{SE^*} = \frac{k^2(a_0 - c_m)^2}{[6k-(\Delta - B)^2]^2} + \frac{\rho V}{9}, \quad \pi_{sc}^{SE^*} = \frac{k(a_0 - c_m)^2}{[6k-(\Delta - B)^2]^2} + \frac{2\rho V}{9}.
\]

We can observe that since the entrant retailer obtains the forecast information, its order quantity is equal to the order quantity of the incumbent retailer. Moreover, the order quantities increase with the forecast value \((A)\). Consequently, the two retailers’ expected profits keep the same. And, the expected profits increase in the forecast accuracy \((\rho)\). The reason of the results is similar to that in scenario 1.

4.3. Scenario 3: sharing information with the manufacturer (SS)

The incumbent retailer will share its demand forecast information with the manufacturer under this scenario. The manufacturer sets the collection rate and wholesale price according to the forecast information. As mentioned above, because of the information leakage effect, the entrant retailer could infer the forecast information based on the adjusted collection rate and wholesale price. Consequently, the entrant retailer also knows the demand forecast information. Therefore, the CLSC members’ decision functions in this scenario can be written as follows:

\[
\max_{\tau,w} E(\pi_m^{SS}|f) = E[(w - c_m + (\Delta - B)\tau)(q_i + q_e) - k\tau^2|f],
\]
\[
\max_{q_i} E(\pi_i^{SS}|f) = E[(a - q_i - q_e - w)q_i|f],
\]
\[
\max_{q_e} E(\pi_e^{SS}|f) = E[(a - q_i - q_e - w)q_e|f].
\]
Similarly, we get the unique equilibrium outcome as shown in Lemma 3.

Lemma 3. Under SS scenario, the optimal wholesale price \( w_{SS}^* \), the optimal collection rate \( \tau_{SS}^* \), the incumbent retailer’s optimal order quantity \( q_{iSS}^* \) and the entrant retailer’s optimal order quantity \( q_{eSS}^* \) are given by

\[
w_{SS}^* = \frac{3k(A + c_m) - A(\Delta - B)^2}{6k - (\Delta - B)^2}, \quad \tau_{SS}^* = \frac{(A - c_m)(\Delta - B)}{6k - (\Delta - B)^2}.
\]

Then, the manufacturer’s expected profit \( \pi_{mSS}^* \), the incumbent retailer’s expected profit \( \pi_{iSS}^* \) and the entrant retailer’s expected profit \( \pi_{eSS}^* \), and the expected profit of the whole CLSC \( \pi_{SS}^* \) are given by

\[
\pi_{mSS}^* = \frac{k(a_0 - c_m)^2}{6k - (\Delta - B)^2} + \frac{k\rho V}{6k - (\Delta - B)^2},
\]

\[
\pi_{iSS}^* = \pi_{eSS}^* = \frac{k^2(a_0 - c_m)^2}{[6k - (\Delta - B)^2]^2} + \frac{k^2\rho V}{[6k - (\Delta - B)^2]^2},
\]

\[
\pi_{SS}^* = \frac{k(a_0 - c_m)^2}{6k - (\Delta - B)^2} + \frac{k\rho V}{6k - (\Delta - B)^2}.
\]

Based on the optimal decisions, we can find that the collection rate of manufacturer increases with the demand forecast value \( A \). The intuition is that a larger \( A \) indicates a higher demand, thereby the manufacturer is able to collect more used products as the increase of collection rate. Interestingly, our result shows that the wholesale price of the manufacturer is decreasing in the forecast value if \( k < (\Delta - B)^2/3 \) and increasing otherwise. When the manufacturer’s collection investment efficiency is high, a larger \( A \) encourages the manufacturer to collect more used products. As the result, the production cost decreases a lot, hence the manufacturer will benefit by decreasing its wholesale price to increase sales. When the manufacturer’s collection investment efficiency is low, a larger \( A \) encourages the manufacturer to increase its wholesale price to gain more profit margin. Moreover, with the increase of forecast accuracy \( \rho \), it will generate positive effects on the manufacturer’s profit. That’s because a higher accurate forecast allows the manufacturer to make better decisions to maximize its profit.

### 5. Comparison of the Three Information Sharing Scenarios

In this section, we compare the above optimal results, thereby investigating the influence of different information sharing strategies of the incumbent retailer on the CLSC. The analysis outcomes are presented in Proposition 1–5. Proofs of all propositions are shown in Appendix A.

Proposition 1. (i) If \( A > a_0 \), the wholesale prices in the three information sharing scenarios are related as follows:

1. If \( k < (\Delta - B)^2/3 \), then \( w_{NI}^* = w_{SE}^* > w_{SS}^* \);
2. If \( k > (\Delta - B)^2/3 \), then \( w_{SS}^* > w_{NI}^* = w_{SE}^* \).

(ii) If \( A > a_0 \), the collection rates in the three information sharing scenarios are related as \( \tau_{SS}^* > \tau_{NI}^* = \tau_{SE}^* \).

Proposition 1(i) indicates that, the wholesale price of the manufacturer in scenario 1 equals to the wholesale price in scenario 2, since the manufacturer does not have the demand forecast information in these two scenarios.
Proposition 2. If $A > a_0$, the retailers’ order quantities in three information sharing scenarios are:

1. If $k < \frac{(\Delta-B)^2}{4}$, then $q_{i}^{SS^*} = q_e^{SS^*} > q_i^{NI^*} > q_i^{SE^*} > q_e^{NI^*}$;
2. If $\frac{(\Delta-B)^2}{4} < k < \frac{(\Delta-B)^2}{3}$, then $q_i^{NI^*} > q_i^{SS^*} = q_e^{SS^*} > q_i^{SE^*} = q_e^{SE^*} > q_e^{NI^*}$;
3. If $k > \frac{(\Delta-B)^2}{3}$, then $q_i^{NI^*} > q_i^{SE^*} = q_e^{SE^*} > q_i^{SS^*} = q_e^{SS^*} > q_e^{NI^*}$.

Proposition 2 suggests that the order quantities of the two retailers are the same under the scenario 2 and scenario 3, because both retailers have the demand forecast information under these two scenarios. And the forecast information and the investment cost-efficiency are the pivotal factors that affect the order quantities of retailers under the two scenarios. Proposition 2 also suggests that the entrant retailer’s order quantity in scenario 1 is the least due to the absence of the positive demand forecast information. Furthermore, it shows that when the forecast demand is greater than the mean demand, the order quantities of the retailers in scenario 3 is the most if the manufacturer’s collection investment efficiency is high, otherwise the order quantity of the incumbent retailer in scenario 1 is the most if the manufacturer’s collection investment efficiency is moderate and low. That’s because the wholesale price is adjusted by the manufacturer based on the forecast information and collection investment efficiency.

Proposition 3. (i) The expected profits of the manufacturer in the three information sharing scenarios are related as $\pi_m^{SS^*} > \pi_m^{NI^*} = \pi_m^{SE^*}$.

(ii) The expected profits of the entrant retailer in the three scenarios with information shared are related as follows:
1. If $k < \frac{(\Delta-B)^2}{3}$, then $\pi_e^{SS^*} > \pi_e^{SE^*} > \pi_e^{NI^*}$;
2. If $k > \frac{(\Delta-B)^2}{3}$, then $\pi_e^{SE^*} > \pi_e^{SS^*} > \pi_e^{NI^*}$.

This proposition reveals the effects of the incumbent retailer’s information sharing strategies on other CLSC participants. Proposition 3(i) shows that, the manufacturer always benefits from the demand information sharing. The intuition is that when obtaining the demand information, the manufacturer could adjust its pricing strategy and reduces the influence of demand uncertainty on it, thereby increasing its expected profits. In addition, the manufacturer makes its decisions first, so the demand information of the entrant retailer has no effect on the expected profit of the manufacturer who doesn’t have the forecast information.

Proposition 3(ii) indicates that when the entrant retailer could not obtain the forecast information, the relatively large double marginalization hurts its expected profit. Hence, the entrant retailer gets the least profit in scenario 1. Moreover, it shows that when the manufacturer’s collection investment efficiency is high (low), due to the low wholesale price and high selling quantity as shown in Propositions 1 and 2, the entrant retailer gets more profit in scenario 3 (scenario 2).

Proposition 4. The expected profits of the incumbent retailer in three information sharing scenarios are:

1. If $k < \frac{(\Delta-B)^2}{4}$, then $\pi_i^{SS^*} > \pi_i^{NI^*} > \pi_i^{SE^*}$;
2. If $\frac{(\Delta-B)^2}{4} < k < \frac{(\Delta-B)^2}{3}$, then $\pi_i^{NI^*} > \pi_i^{SS^*} > \pi_i^{SE^*}$;
(3) If \( k > \frac{(\Delta - B)^2}{3} \), then \( \pi_i^\text{NI} > \pi_i^\text{SE} > \pi_i^\text{SS} \).

Proposition 4 indicates the preference of the information sharing preference about the incumbent retailer. We can find that under the three information sharing scenarios, the profit ranking of the incumbent retailer is the same as the ranking relationship of its order quantity as shown in Proposition 2. This is because we consider a Cournot competition between the retailers. The order quantities determine the product price and selling quantities. Therefore, when the manufacturer’s collection investment efficiency is high, the incumbent retailer prefers to share its demand forecast information with the manufacturer, because it can obtain more profit through the high selling quantities. Otherwise, when the manufacturer’s collection investment efficiency is moderate and low, the incumbent retailer is unwilling to share its forecast information under the low selling quantities.

Proposition 5. According to the comparison of the whole CLSC expected profits, we find that:

1. If \( k < \frac{2 + \sqrt{3}}{2} (\Delta - B)^2 \), then \( \pi_{sc}^\text{SS} > \pi_{sc}^\text{NI} > \pi_{sc}^\text{SE} \);
2. If \( k > \frac{2 + \sqrt{3}}{2} (\Delta - B)^2 \), then \( \pi_{sc}^\text{NI} > \pi_{sc}^\text{SS} > \pi_{sc}^\text{SE} \).

Based on Proposition 5, interestingly, we find that will be harmful to the whole CLSC when the incumbent retailer shares its forecast information only with the entrant retailer. It indicates that sharing demand forecast information with other CLSC members is not always beneficial to the whole CLSC. When only the entrant retailer obtains the information, the increased double marginalization between the manufacturer and the entrant retailer will hurt the whole CLSC. However, it also indicates that sharing information with the manufacturer benefits the whole CLSC if the manufacturer’s collection investment efficiency is high. The reason is that when the manufacturer possesses the forecast information, the profit increases of the entrant retailer and the manufacturer are larger than the profit loss of the incumbent retailer if the collection investment efficiency is high, thereby maximizing the expected profit of the whole CLSC.

6. INFORMATION ACQUISITION BY A PAYMENT

As in Shang et al. [37] and Lei et al. [23], next, we explore that whether other participants in the CLSC could obtain the demand forecast information of the incumbent retailer through a payment. Suppose that the manufacturer or the entrant retailer provides a payment \( T \) to the incumbent retailer for the forecast information at the beginning of the game. Note that, such information sharing arrangement through a payment can be achieved only if the expected profit of the whole CLSC with forecast information is larger than that without forecast information. Otherwise, the profit loss of the incumbent retailer deriving from the information sharing can’t be compensated. From Proposition 5, we note that the expected profit of the whole CLSC in scenario 2 is the least in the three information sharing scenarios. Thus, the entrant retailer can not get the forecast information of the incumbent retailer by a side payment. Furthermore, from Propositions 3–5, it shows that since the entrant retailer can also know the forecast information of the incumbent retailer in scenario 3, the manufacturer and the entrant retailer can obtain the demand forecast information of the incumbent retailer through a payment only if \( \frac{(\Delta - B)^2}{4} < k < \frac{2 + \sqrt{3}}{2} (\Delta - B)^2 \). Consequently, we can get the following proposition with respect to the information sharing arrangement by a payment.

Proposition 6. (i) The entrant retailer always can’t obtain the demand forecast information of the incumbent retailer through a side payment.
   (ii) If \( \frac{(\Delta - B)^2}{4} < k < \frac{2 + \sqrt{3}}{2} (\Delta - B)^2 \), both the manufacturer and the entrant retailer can obtain the demand forecast information of the incumbent retailer through a payment.

Based on Proposition 6, we know that the entrant retailer can’t obtain the demand forecast information of the incumbent retailer through a side payment. Then a natural question arises: is there an effective mechanism to solve this problem? Similar to Kong et al. [22], we propose an alliance between the two retailers to solve
this problem. Specifically, when the incumbent retailer doesn’t share its demand forecast information with the entrant retailer, given the manufacturer’s wholesale price and collection rate, the two retailers form an alliance in which the incumbent retailer shares the forecast information with the entrant retailer and they together decide the order quantity to maximize their total profit. We present this effective mechanism to obtain information for the entrant retailer in the following proposition. The proof is shown in the Appendix A.

**Proposition 7.** When the incumbent retailer doesn’t share the demand forecast information with the entrant retailer, the entrant retailer can obtain the incumbent retailer’s information through an alliance strategy.

In addition, an interesting and important situation may occur, that is, when the incumbent retailer only shares the demand forecast information with the entrant retailer, the entrant retailer may have an incentive to leak the information to the manufacturer. From Proposition 3, we can find that if \( k < \frac{(\Delta - B)^2}{3} \), the entrant retailer has an incentive to leak the demand forecast information to the manufacturer. On the other hand, from Proposition 4, we note that if \( k < \frac{(\Delta - B)^2}{3} \), the incumbent retailer’s expected profit increases when the manufacturer obtains the information from the entrant retailer. This is a new and interesting insight. We present this finding in the following proposition.

**Proposition 8.** When the incumbent retailer only shares the demand information with the entrant retailer, if \( k < \frac{(\Delta - B)^2}{3} \), the entrant retailer has an incentive to leak the information to the manufacturer and this behavior makes the incumbent retailer better off.

### 7. Numerical experiment

In this section, similar to Wang et al. [47] and Hu et al. [14], we conduct several numerical studies to further verify our theoretical results. Specifically, we analyze the effects of the incumbent retailer’s demand forecast value \((A)\) and forecast accuracy \((\rho)\), and demand uncertainty \((V)\) on the CLSC participants’ decisions and expected profits. Referring to Huang and Wang [16] and Cai et al. [3], the parameters used in numerical studies are as follows: \( a_0 = 250, c_m = 10, c_r = 4, B = 2, k = 250 \).

#### 7.1. The influences of \( A \) on the CLSC members’ decisions

In this subsection, we investigate the impacts of forecast value \( A \) on the manufacturer’s wholesale price, collection rate and the retailers’ order quantities. We vary the value of \( A \) from 200 to 300. The changes of the CLSC members’ decisions with \( A \) are shown in Figures 2–4. From Figures 2 and 3, we note that when the incumbent retailer doesn’t share information or only shares the information with the entrant retailer, the manufacturer would set the same wholesale price and collection rate under the two cases and the forecast value \( A \) has no impact on the wholesale price and collection rate since the manufacturer doesn’t have the forecast information. However, when the incumbent retailer shares the information with the manufacturer, as the forecast value \( A \) increases, the manufacturer would increase the wholesale price and collection rate to obtain more marginal profit. Since we set a high value of \( k \), Figures 2 and 3 show that if \( A > a_0 = 250 \), then \( w_{SS}^* > w_{NI}^* = w_{SE}^* \) and \( \tau_{SS}^* > \tau_{NI}^* = \tau_{SE}^* \), and if \( A < a_0 = 250 \), then \( w_{SS}^* < w_{NI}^* = w_{SE}^* \) and \( \tau_{SS}^* < \tau_{NI}^* = \tau_{SE}^* \), which are consistent with Proposition 1.

Figure 3 shows that when the entrant retailer has no forecast information, its order quantity is not affected by the forecast value \( A \). Nevertheless, when the entrant retailer obtains the forecast information of the incumbent retailer, with the increase of the forecast value \( A \), the retailers would increase the order quantities to satisfy the demand of market. Moreover, because we set a high \( k \), Figure 3 presents that if \( A > a_0 = 250 \), then \( q_{NI}^* > q_{SE}^* > q_{c}^* > q_{SS}^* > q_{c}^* > q_{NI}^* \), which corresponds to Proposition 2.
7.2. The influences of $\rho$ on the CLSC members’ expected profits

In this subsection, we examine the impacts of forecast accuracy $\rho$ on the manufacturer’s expected profit and the retailers’ expected profits. Assuming that $V = 50$, we make $\rho \in [0, 1]$. The impacts are shown in Figures 5–7. From Figure 5, it is obvious that the manufacturer’s expected profit is not affected by the forecast accuracy $\rho$ when the manufacturer doesn’t have the forecast information. Figure 5 shows that when the manufacturer owns the forecast information, in accordance with Proposition 3, its expected profit increases with the forecast accuracy $\rho$, and $\pi^*_{SS} > \pi^*_{NI} = \pi^*_{SE}$. As a result, the information sharing value for the manufacturer ($\pi^*_{SS} - \pi^*_{NI}$) increases with the forecast accuracy $\rho$. Figures 6 and 7 show that when the entrant retailer obtains the incumbent retailer’s demand forecast information, the expected profits of both retailers increase with the forecast accuracy $\rho$. Thus, the incumbent retailer has its own motivation for increasing the forecast accuracy. In
addition, because we assume a high $k$, Figures 6 and 7 show that $\pi_i^{NI^*} > \pi_i^{SE^*} > \pi_i^{SS^*}$ and $\pi_e^{SE^*} > \pi_e^{SS^*} > \pi_e^{NI^*}$, which correspond to Propositions 3 and 4.

7.3. The influences of $V$ on the CLSC members’ expected profits

We explore the effects of demand uncertainty $V$ on the manufacturer’s expected profit and the retailers’ expected profits. We make the demand uncertainty $V \in [50, 100]$ under $\rho = 0.8$ and the effects are presented in Figures 8–10. Figure 8 shows that when the manufacturer makes decisions without the demand forecast information, the demand uncertainty has no impact on the manufacturer’s expected profit. When the manufacturer possesses the demand forecast information, its expected profit increases with the demand uncertainty $V$, which means that the demand forecast information eliminates the negative impact of demand uncertainty. Figures 9 and 10 present that if the entrant retailer gets the demand forecast information, the expected profits
8. Conclusion

We study a CLSC made up of one common manufacturer, one incumbent retailer and one entrant retailer. The two retailers compete with each other in the market. They purchase the same products from the manufacturer, and then sell them to the consumers. We consider that the incumbent retailer owns private forecast information with respect to the market demand. It can strategically share the forecast information with other CLSC participants to make great profits. Our aim is to investigate the impacts of different information sharing strategies of the incumbent retailer on the CLSC, and explore the incumbent retailer’s incentives to share...
its forecast information. Furthermore, we discuss the influences of forecast accuracy and forecast value on the optimal decisions of the CLSC members. Our work provides some guidelines for the practitioners who are in a similar CLSC context.

Based on our analysis results, our work points to several interesting managerial insights. Firstly, the information sharing strategies of the incumbent retailer and the manufacturer’s collection investment efficiency play important roles in the CLSC members’ decisions. Secondly, due to the information leakage effect, no matter the incumbent retailer shares the forecast information with the entrant retailer or the manufacturer, it is always beneficial to the entrant retailer. And when the manufacturer is efficient in collection investment, sharing information with the manufacturer is better for the entrant retailer. Thirdly, from incumbent retailer’s perspective, sharing demand forecast information with the manufacturer will benefit for itself when the manufacturer is
highly efficient in collection investment. Otherwise, it will hurt itself to share the information. Fourthly, the entrant retailer always can’t obtain the incumbent retailer’s demand information by a side payment. This finding is consistent with the real case. For instance, the Wal-Mart isn’t willing to share its forecast information about product demand with the competitor as mentioned in Introduction. Nevertheless, if the investment efficiency of the manufacturer meets certain conditions, the entrant retailer and the manufacturer could get the demand information through a payment.

There are several limitations that could be further studied in the future. Firstly, we consider the product categories in which the remanufactured products reach the quality standards of manufactured ones. In reality, in some product categories, the remanufactured products may be not upgraded to the quality specifications of new ones. Hence, it will be interesting if future research considers this case. Secondly, we suppose that only the incumbent retailer possesses the demand forecast information. In practice, as an entrant, facing the uncertain market demand, the entrant retailer may also have demand forecast information by some information acquisition methods (e.g., consulting or survey). It would be interesting to discuss the effect of different information sharing on the CLSC under this case. Last but not least, we only consider the downstream retailer competition. It would be meaningful to explore the case of upstream supplier competition in the future.

**Appendix A.**

*Proof of Lemma 1.* Taking the second derivative of \( \pi_{NI}^i \) with respect to \( q_i \), we get \( \frac{d^2 E(\pi_{NI}^i|f)}{dq_i^2} = -2 < 0 \). Similarly, we get \( \frac{d^2 E(\pi_{NI}^e)}{dq_e^2} = -2 < 0 \). Thus, \( E(\pi_{NI}^i|f) \) is concave in \( q_i \) and \( E(\pi_{NI}^e) \) is concave in \( q_e \). Let \( \frac{dE(\pi_{NI}^i|f)}{dq_i} = 0 \) and \( \frac{dE(\pi_{NI}^e)}{dq_e} = 0 \). We obtain the response functions \( q_i = \frac{A-w-q_e}{2} \) and \( q_e = \frac{a_0-w-q_i}{2} \). Note that the entrant retailer does not know the forecast information. Hence, the entrant retailer anticipates that the incumbent retailer’s response function is \( q_i = \frac{a_0-w-q_e}{2} \). Substituting this response function into \( q_e = \frac{a_0-w-q_i}{2} \), we get that \( q_e = \frac{a_0-w}{3} \).

Anticipating the entrant retailer’s decision function, we get that \( q_i = \frac{3A-a_0-2w}{6} \). Because the manufacturer does not know the forecast information, the manufacturer anticipates that the entrant retailer’s and the incumbent retailer’s response functions are \( q_e = \frac{a_0-w}{3} \) and \( q_i = \frac{a_0-w}{3} \). Substituting these response functions into the
Thus, the Hessian matrix is

\[
\frac{\partial^2 E(\pi^\text{NI}_m)}{\partial w^2} = \frac{2}{3}(a_0 - 2w + c_m + B\tau - \Delta), \quad \frac{\partial^2 E(\pi^\text{NI}_m)}{\partial \tau^2} = \frac{2}{3}(a_0 - w)(\Delta - B) - 2k\tau,
\]

Since \(|H| = \frac{2}{9}k - \frac{4}{9}(\Delta - B)^2 > 0\) if \(k > \frac{(\Delta - B)^2}{6}\), it shows that \(E(\pi^\text{NI}_m)\) is joint concave in \(w\) and \(\tau\). Let \(\frac{\partial E(\pi^\text{NI}_m)}{\partial w} = \frac{\partial E(\pi^\text{NI}_m)}{\partial \tau} = 0\). The equilibrium decisions of the manufacturer are given by

\[
w^{\text{NI}} = \frac{3k(a_0 + c_m) - a_0(\Delta - B)^2}{6k - (\Delta - B)^2}, \quad \tau^{\text{NI}} = \frac{(a_0 - c_m)(\Delta - B)}{6k - (\Delta - B)^2}.
\]

Substituting \(w^{\text{NI}}\), \(\tau^{\text{NI}}\) into \(q_i = \frac{3A - a_0 - 2w}{6}\) and \(q_e = \frac{a_0 - w}{3}\), we get the two retailers’ optimal selling quantities as follows:

\[
q^{\text{NI}}_i = \frac{2k(3A - 2a_0 - c_m) + (a_0 - A)(\Delta - B)^2}{2\left[6k - (\Delta - B)^2\right]}, \quad q^{\text{NI}}_e = \frac{k(a_0 - c_m)}{6k - (\Delta - B)^2}.
\]

Then, substituting \(w^{\text{NI}}\), \(\tau^{\text{NI}}\), \(q^{\text{NI}}_i\) and \(q^{\text{NI}}_e\) into the expected profit functions of the CLSC participants, we get the participants’ expected profits (i.e., \(\pi^{\text{NI}}_m\), \(\pi^{\text{NI}}_i\), \(\pi^{\text{NI}}_e\)) as shown in Lemma 1. Finally, we get the whole CLSC’s expected profit \(\pi^{\text{NI}}_{sc} = \pi^{\text{NI}}_m + \pi^{\text{NI}}_i + \pi^{\text{NI}}_e\).

The proofs of Lemma 2 and 3 are similar. Hence, we omit them.

**Proof of Proposition 1.** Based on Lemmas 1 and 2, it is obvious that \(w^{\text{NI}} = w^{\text{SE}}\) and \(\tau^{\text{NI}} = \tau^{\text{SE}}\). Then we compare \(w^{\text{SS}}\) with \(w^{\text{NI}}\) (or \(w^{\text{SE}}\)) and get the following:

\[
w^{\text{SS}} - w^{\text{NI}} = \frac{3k(\Delta - B)^2}{6k - (\Delta - B)^2} (A - a_0).
\]

It shows that when \(A > a_0\), \(w^{\text{SS}} > w^{\text{NI}}\) if \(k > \frac{(\Delta - B)^2}{4}\), and \(w^{\text{SS}} < w^{\text{NI}}\) if \(k < \frac{(\Delta - B)^2}{4}\). Next, we compare \(\tau^{\text{SS}}\) with \(\tau^{\text{NI}}\) (or \(\tau^{\text{SE}}\)) and obtain the following:

\[
\tau^{\text{SS}} - \tau^{\text{NI}} = \frac{(\Delta - B)(A - a_0)}{6k - (\Delta - B)^2}.
\]

We can derive that \(\tau^{\text{SS}} > \tau^{\text{NI}}\) if \(A > a_0\). As a result, we prove the Proposition 1. \(\square\)
Proof of Proposition 2. Based on Lemmas 2 and 3, it is obvious that \( q_{i}^{SS^*} = q_{e}^{SE^*} \) and \( q_{i}^{SS^*} = q_{e}^{SS^*} \). Then we compare the equilibrium selling quantities and get the following:

\[
q_{i}^{SS^*} - q_{i}^{NI^*} = -\frac{4k-(\Delta - B)^2}{6k-(\Delta - B)^2}(A-a_0),
\]

\[
q_{i}^{SS^*} - q_{e}^{NI^*} = \frac{k(A-a_0)}{6k-(\Delta - B)^2},
\]

\[
q_{i}^{SS^*} - q_{i}^{SE^*} = -\frac{3k-(\Delta - B)^2}{6k-(\Delta - B)^2}(A-a_0),
\]

\[
q_{i}^{SE^*} - q_{i}^{NI^*} = -\frac{(A-a_0)}{6},
\]

\[
q_{i}^{SE^*} - q_{e}^{NI^*} = \frac{(A-a_0)}{3}.
\]

Hence, we can derive that when \( A > a_0 \), \( q_{i}^{SS^*} = q_{e}^{SS^*} > q_{i}^{NI^*} > q_{i}^{SE^*} = q_{e}^{SE^*} > q_{i}^{NI^*} \) if \( k < \frac{(\Delta - B)^2}{4}, q_{i}^{NI^*} > q_{i}^{SS^*} > q_{e}^{SS^*} > q_{e}^{SE^*} > q_{e}^{NI^*} \), if \( k > \frac{(\Delta - B)^2}{3} \).

Proof of Proposition 3. Based on Lemmas 1 and 2, we can see that \( \pi_{m}^{NI^*} = \pi_{m}^{SE^*} \). Then we compare \( \pi_{m}^{SS^*} \) with \( \pi_{m}^{NI^*} \) (or \( \pi_{m}^{SE^*} \)) and gain the following:

\[ \pi_{m}^{SS^*} - \pi_{m}^{NI^*} = \frac{kpV}{6k-(\Delta - B)^2} > 0. \]

Consequently, we obtain that

\[ \pi_{m}^{SS^*} > \pi_{m}^{NI^*} = \pi_{m}^{SE^*}. \]

Moreover, comparing the expected profits of the entrant retailer, we can get the following:

\[ \pi_{e}^{SS^*} - \pi_{e}^{NI^*} = \frac{k^2pV}{6k-(\Delta - B)^2} > 0. \]

\[ \pi_{e}^{SS^*} - \pi_{e}^{SE^*} = -\frac{9k-(\Delta - B)^2}{6k-(\Delta - B)^2}pV, \]

\[ \pi_{e}^{SE^*} - \pi_{e}^{NI^*} = \frac{pV}{9} > 0. \]

We note that \( \pi_{e}^{SS^*} > \pi_{e}^{NI^*} \) and \( \pi_{e}^{SE^*} > \pi_{e}^{NI^*} \). Moreover, it shows that \( \pi_{e}^{SS^*} > \pi_{e}^{SE^*} \) if \( k < \frac{(\Delta - B)^2}{3} \), and \( \pi_{e}^{SE^*} > \pi_{e}^{SS^*} \) otherwise. Consequently, we derive that \( \pi_{e}^{SS^*} > \pi_{e}^{SE^*} > \pi_{e}^{NI^*} \) if \( k < \frac{(\Delta - B)^2}{3} \), \( \pi_{e}^{SE^*} > \pi_{e}^{SE^*} > \pi_{e}^{SS^*} > \pi_{e}^{NI^*} \) otherwise. \( \Box \)

Proof of Proposition 4. We compare the expected profits of the incumbent retailer and obtain the following:

\[ \pi_{i}^{SS^*} - \pi_{i}^{NI^*} = -\frac{8k-(\Delta - B)^2}{4}[k-(\Delta - B)^2](\Delta - B)^2 \rho V. \]
\[ \pi_{sc}^{SS} - \pi_{sc}^{NI} = -\frac{[9k-(\Delta-B)^2][3k-(\Delta-B)^2]pV}{9[6k-(\Delta-B)^2]^2}, \]

\[ \pi_{sc}^{SE} - \pi_{sc}^{NI} = -\frac{5pV}{36} < 0. \]

Obviously, \( \pi_{sc}^{SS} < \pi_{sc}^{NI} \). In addition, we can get that \( \pi_{sc}^{SS} > \pi_{sc}^{NI} \) if \( k < \frac{(\Delta-B)^2}{4} \), \( \pi_{sc}^{SS} > \pi_{sc}^{SE} \) if \( k < \frac{(\Delta-B)^2}{3} \), and \( \pi_{sc}^{SE} < \pi_{sc}^{NI} \) if \( k > \frac{(\Delta-B)^2}{3} \). As a result, we can derive that \( \pi_{sc}^{SS} > \pi_{sc}^{NI} > \pi_{sc}^{SE} \) if \( k < \frac{(\Delta-B)^2}{4} \), \( \pi_{sc}^{NI} > \pi_{sc}^{SS} > \pi_{sc}^{SE} \) if \( \frac{(\Delta-B)^2}{3} < k < \frac{(\Delta-B)^2}{3} \), and \( \pi_{sc}^{NI} > \pi_{sc}^{SE} > \pi_{sc}^{SS} \) if \( k > \frac{(\Delta-B)^2}{3} \). \( \square \)

**Proof of Proposition 5.** We compare the expected profits of the whole CLSC and get the following:

\[ \pi_{w}^{SS} - \pi_{w}^{NI} = \frac{[4k^2-8(\Delta-B)^2k+(\Delta-B)^4]pV}{4[6k-(\Delta-B)^2]^2}, \]

\[ \pi_{w}^{SE} - \pi_{w}^{NI} = \frac{(\Delta-B)^2[15k-2(\Delta-B)^2]pV}{9[6k-(\Delta-B)^2]^2} > 0, \]

\[ \pi_{w}^{SE} - \pi_{w}^{NI} = -\frac{pV}{36} < 0. \]

It shows that \( \pi_{w}^{SS} > \pi_{w}^{SE} \) and \( \pi_{w}^{SE} < \pi_{w}^{NI} \). Furthermore, let \( L(k) = 4k^2-8(\Delta-B)^2k+(\Delta-B)^4 \). We take the first derivative of \( L(k) \) with respect to \( k \) and get that \( \frac{dL(k)}{dk} = 8k-8(\Delta-B)^2 \). Let \( \frac{dL(k)}{dk} = 0 \), we can derive two roots \( k_1 = \frac{2+\sqrt{3}(\Delta-B)^2}{2} \) and \( k_3 = \frac{2+\sqrt{4}(\Delta-B)^2}{2} \). Note that \( k_1 < \frac{(\Delta-B)^2}{6} \) and \( k_2 > \frac{(\Delta-B)^2}{6} \). Hence, we derive that \( \pi_{w}^{SS} > \pi_{w}^{NI} > \pi_{w}^{SE} \) if \( k < \frac{2+\sqrt{3}(\Delta-B)^2}{2} \), and \( \pi_{w}^{NI} > \pi_{w}^{SS} > \pi_{w}^{SE} \) if \( k > \frac{2+\sqrt{3}(\Delta-B)^2}{2} \). \( \square \)

**Proof of Proposition 7.** Under scenario 1, when the two retailers form an alliance, the incumbent retailer shares its demand forecast information with the entrant retailer. Therefore, given the manufacturer’s wholesale price \( w^{NI} \), the profit function of the alliance is \( \pi_{rr} = (A - q_i - q_e - w^{NI})(q_i + q_e) \). We take the first derivative of \( \pi_{rr} \) with respect to \( q_i + q_e \) and get the optimal order quantities under this alliance scenario as follows:

\[ q_i^* + q_e^* = \frac{1}{2} A + \frac{a_0(\Delta-B-3a_0k-3c_mk)}{2[6k-(\Delta-B)^2]^2}. \]

Then, substituting \( q_i^* + q_e^* \) into \( \pi_{rr} \), we get the optimal profit of the alliance as follows:

\[ \pi_{rr}^* = \frac{9k^2(a_0-c_m)^2}{4[6k-(\Delta-B)^2]^2} + \frac{pV}{4}. \]

We compare \( \pi_{rr}^* \) and \( \pi_{i}^{NI} + \pi_{i}^{SE} \) and get the following:

\[ \pi_{rr}^* - (\pi_{i}^{NI} + \pi_{i}^{SE}) = \frac{k^2(a_0-c_m)^2}{4[6k-(\Delta-B)^2]^2} > 0. \]

Thus, the two retailers have an incentive to form an alliance. And meanwhile, the entrant retailer obtains the demand forecast information of the incumbent retailer. Then, the two retailers negotiate to share the profit. \( \square \)
REFERENCES

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